A DETERMINATION OF THE GENERALIZATIONS IN THE FIRST YEAR SCIENCE COURSES OF ALBERTA HIGH SCHOOLS

THE UNIVERSITY OF ALBERTA

A DETERMINATION OF THE GENERALIZATIONS IN THE FIRST YEAR SCIENCE COURSES OF ALBERTA HIGH SCHOOLS

A DISSERTATION

SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR

THE DEGREE OF MASTER OF EDUCATION

FACULTY OF EDUCATION

BY

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EDMONTON, ALBERTA

May, 1945

TABLE OF CONTENTS

CHAPTER		Page
I	PURPOSE OF THE INVESTIGATION	1
	DEFINITION OF TERMS	1
	THE PROBLEM	2
	Limitations of the Problem	3
II	METHODS AND MATERIALS	
	Method	4
	Materials	6
III	DATA FOR BIOLOGY I	
	Generalizations	7
	Diagrams to be learned	25
	Experiments and activities to be performed	28
IV	DATA FOR CHEMISTRY I	
	Generalizations	32
	Diagrams to be learned and activities to be performed	49
V	DATA FOR PHYSICS I	
	Generalizations	52
	Diagrams to be learned and activities to be performed	75
VI	DATA FOR GEOLOGY I	
	Generalizations	82
	Diagrams to be learned	101
	Experiments and activities to be performed	103
VII	SUMMARY AND CONCLUSIONS	
	Table I - Summary of data	106
	Conclusions regarding the Biology I course	107
	Conclusions regarding the Chemistry I course	111
	Conclusions regarding the Physics I course	113

TABLE OF CONTENTS (continued)

Page

Conclusions regarding the Geology I course 115
General conclusions 117
Implications 118

VIII CRITICISMS AND SUGGESTIONS

Biology I 120
Chemistry I 122
Physics I 123
Geology I 125
General comment 127
Research needed 132

ACKNOWLEDGEMENTS 136

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Norman Edwin Lougheed

INTRODUCTION

One of the commonest criticisms which the science teacher hears against present science courses in most Canadian high schools is that these courses are too detailed and too unrelated to each other to provide the student with the basic generalizations which best enable him to understand his environment and appreciate the relationship of science to everyday life. This type of criticism has been directed chiefly against first-year science courses. It has resulted in a definite trend toward teaching these courses not as specialized subjects but as a single course in "General Science", in which increased emphasis is placed upon the generalizations and the inherent unity of all the sciences. Some provinces in Canada have already abandoned the system of teaching first-year science as specialized courses, and have introduced instead one course of General Science for each year of the high school. These General Science courses are designed to acquaint the first-year student with those fundamental

aspects of science which illuminate everyday life, yet which at the same time form a broad enough basis for further and more intensive study in any of the specialized fields of science.

Educators are generally well agreed that this is one of the chief objectives[1] of science education; and almost every course of study in first-year science for high schools makes it clear that the instructional material must emphasize the basic principles of science and also provide an abundant opportunity for the student to learn to formulate clearly the generalizations which will clarify and unify the field of science for him.

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[1](a) Preliminary Report of the Science Committee to the Commission on Secondary School Curriculum of the Progressive Education Association, 1936, Part II, p.1.

(b) A Programme for Teaching Science, 31st Year Book, Part I, National Society for the Study of Education. Public School Publishing Co., Bloomington, Ill., 1932

CHAPTER I

PURPOSE OF THE INVESTIGATION

It is the purpose of the following investigation to determine the generalizations contained in the authorized text books for four of the first-year science courses of the Alberta High Schools. It is hoped that in this way science teachers may have a more objective means by which to determine:

(a) The extent to which present first-year science courses in Alberta provide the student with basic science generalizations or principles, and

(b) The approximate "learning load" which a reasonable mastery of these courses presents to each pupil.

DEFINITION OF TERMS

By "generalization" we shall mean a broad concept of a fundamental truth perceived as a basic operative factor in a wide variety of phenomena.

It must be realized that the term "generalization" as used in this investigation "stands both for a process and the result of that process"[1]. It is true that the student

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[1] A Programme for Teaching Science. 31st Year Book, Part I; National Society for the Study of Education. Public School Publishing Co., Bloomington, Ill., 1932

must understand the basic principles of natural science in their wider relationships, but he should arrive at such understanding through discovery and the exercise of reason upon the great variety of phenomena which he perceives about him. It is imperative that the student become the active factor in the process of generalization.

By "learning load" we shall mean the average amount of factual and explanatory material which a student must learn during one standard-length period of instruction, in order to obtain a reasonable mastery of the generalizations comprising the core material around which each of the investigated courses has been built.

The explanatory material will be expressed in terms of words of material to be studied.

The factual material will be expressed as the average number of new words, diagrams, experiments and activities, scientific laws, definitions, questions and exercises, etc., which the student must learn during the period of time calculated as available to learn one generalization.

THE PROBLEM

The investigation here reported represents an attempt to discover the nature and number of the generalizations contained in the authorized science books used in Alberta High Schools as text books for the courses in Biology I,

Chemistry I, Physics I, and Geology I, as outlined by the "Programme of Studies for the High Schools" for the year ending July 15, 1945.

Limitations of the Problem

This investigation will be confined wholly to the problem as stated. No attempt is to be made to determine what generalizations should or should not be included as curricular material; and no evaluation is made as to the suitability of the sequence in which these generalizations have been presented, since even those investigators[1] who have made exhaustive studies of a large number of science curricula for High Schools have failed to show any general agreement on these two problems.[2] However, a few general comments have been added regarding the content of each course investigated, and certain suggestions made regarding possible improvements. These comments and suggestions are based entirely upon the experience and opinions of the writer, and should not in any sense be understood as deductions from experimental evidence.

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[1] Heinemann, A.M. "A Study of General Science Text Books". General Science Quarterly. Nov., 1928.

[2] Hiess, Elwood D. "An Investigation of Content and Mastery of High School General Science Courses". Stroudsburg Teachers' College, Pennsylvania, 1932.

CHAPTER II

METHODS AND MATERIALS

Method

The prescribed sections of each of the authorized text books used in the four science courses investigated were very carefully read and each generalization found was recorded on a separate card. These generalizations were, in most cases, taken verbatim from their sources. In cases, however, where the generalization was merely implied or was incompletely stated, the investigator completed it according to the inference of the contextual material, and recorded it in the same way as the others. All scientific words and terms likely to be new to the student and therefore to be a source of language difficulty were carefully listed in alphabetic order and placed after the main generalization to which they referred. They will be found listed under the heading "Vocabulary Expansion Required for Generalization".

Definitions and laws which the student must usually memorize were likewise recorded and placed after the appropriate main generalization. The generalizations were then grouped according to the topics to which they most closely referred. Generalizations and "vocabulary expansions" which

occurred more than once in the same course were recorded only once on the cards for that course; but where the same generalization, word, or term appeared in more than one course, it was recorded in the appropriate place in each course in which it appeared.

In this way all generalizations found in the Chemistry I course appear under the subject heading "Chemistry I"; all those found in Physics I appear under the subject heading "Physics I". The same was done with Biology I and Geology I.

Before being able to determine the learning load for the student, it was necessary to determine not only the number of generalizations and the extent of the language difficulty, but also the number of diagrams, experiments and activities, scientific laws, definitions, questions and exercises, etc., which the student is normally required to learn. Then, knowing the amount of printed material contained in the authorized texts and the amount of time normally allotted to each course, the average learning load per generalization was calculated. The result gives a concrete expression of the minimum learning load which each of these science courses presents to the student.

This investigation has attempted to make clear the number and nature of the generalizations contained in Alberta's first-year science courses, together with the learning load which a reasonable mastery of these generalizations imposes upon the student. It is hoped that this study will enable

science teachers to appraise more accurately how well the text book material authorized for these courses promotes the achievement of the fundamental objectives of science education in high schools.

Materials

The materials used in this investigation consisted only of those sections of the authorized text books prescribed in Bulletin IV of the "Programme of Studies for the High School", issued by the Department of Education for Alberta for the school year which ends July 31, 1945. The authorized text books for each subject investigated were as follows:

Biology I - Pieper, Beauchamp, and Frank: Everyday Problems in Biology. Canadian Edition. W. J. Gage & Co.

Chemistry I - Black and Conant: New Practical Chemistry. Macmillan Company.

Geology - M. B. B. Crockford: Geology for High Schools.

Physics I - Charles E. Dull: Modern Physics (revised edition). Henry Holt & Co.

Merchant and Chant (revised by Lewis Ainslie and Lang): Elements of Physics for Canadian Schools. Copp Clark Company.

CHAPTER III

The primary purpose of this thesis is to present in objective form the various generalizations found in the Biology I, Chemistry I, Geology I, and Physics I courses. Therefore, the data which follow consist entirely of these generalizations organized into major and minor categories under their proper subject headings, together with the words, terms, definitions, and laws, etc., which are related to each major heading and which are likely to present language difficulty to the student.

DATA FOR BIOLOGY I

Generalizations

I. For every living thing life becomes a constant search and struggle for food.

1. Methods of food getting are dependent upon the structure of the organism.
    (a) Animals possess a wide variety of body parts which aid in obtaining food.
    (b) The ways in which an organism gets its food depend upon characteristics inherited from the parents.
2. As we proceed up the scale of animal life--that is, from the simple to the more complex forms--we find an ever increasing variety and specialization of those

body parts which are used to obtain food.

(a) Man, like other animals, has been dependent upon the structure of his body in developing his methods of procuring food.

(i) Through the use of his brain, which is capable of much higher development than is the brain of other animals, man has become the master of the rest of the living world.

3. The methods used by plants to obtain food depend upon the structure of the plant.

(a) Food materials from the soil or water pass into the plant cells by the processes of osmosis and imbibition.

(i) There are certain specialized systems of cells in the plant structure used for transporting food materials.

4. Plants which contain chlorophyll are able to utilize the energy of the sun to produce food materials from the simpler substances obtained from the air, soil, and water.

(a) Energy from the sunlight is stored in the plant body in the form of food material.

(i) Only plants which contain chlorophyll can manufacture foods.

(ii) By the process of oxidation, energy stored in the food materials is released and made

available to the plant cells for growth, repair, and reproductive processes.

5. Animals are dependent upon plants for a food supply, since only plants are capable of converting the raw materials from the air, soil, and water into food materials capable of sustaining animal life.
   (a) Certain plants which lack chlorophyll depend upon other plants or animals to provide food.
6. Wastes from the utilization of foods in the bodies of living things must be removed to maintain the efficiency of the life processes.
7. The protoplasm in living things is the substance which carries on all the activities of life in an organism, and the protoplasm like other materials wears out and must be replaced.
8. The growth and well-being of an organism is affected by the kind as well as the quantity of food which it obtains.
9. All plants and animals have a cellular structure, but the cells may vary greatly in structure, composition, and function.
   (a) The work of the body is really done by the cells which compose it.
10. The physical and chemical properties of foods must be changed by digestive juices before these foods can be used by the living cells.

(a) Animals and plants are equipped with special body parts to aid in the digestion of foods.

(i) Plants and animals produce enzymes which aid in digesting foods.

11. The kind of food used by an organism is closely related to the structure of the organism.

(a) Plant-eating organisms have relatively complex digestive systems and long intestinal tracts.

12. Living things must have some type of transportation system in order that food can reach the cells in every part of the body.

(a) Digested foods pass by diffusion into the cells of the organism.

(b) In the transportation and distribution of food, higher animals differ from higher plants in that animals have organs which drive the food through the body channels.

13. All living things must obtain oxygen to release the energy contained in the cell materials.

(a) The quantity of oxygen required by an organism depends upon the size and the activities of the organism.

(b) In respiration oxygen is absorbed through the cell wall by the cell protoplasm; and wastes pass out from the cell protoplasm through the cell wall.

Vocabulary Expansion Required for Generalization I

abomasum
adaptation
alimentary canal
amoeba
amylopsin
antennae
auricle
bacterium
berri-berri
calorie
capillary
carbohydrate
carnivorous
cellulose
chemical decomposition
chlorophyll
chloroplast
cilia
ciliated
compounds
contractile vacuole
corpuscular
cytoplasm
elements
enzymes
epidermis
esophagus
fibro-vascular bundles
Fehling's solution
fungi
gastric juice
glycogen
haustoria
hay infusion
herbivors
hibernate
host
hydra
hyphae
imbibition
insectivorous
lacteals
larvae
lenticels
lipase
lymph
mammal
mandible
mesophyll
mycelium
nucleus
omasum
omnivorous
oral groove
organ
osmotic pressure
oxidation
oxygenation
palisade cell
pancreatic
paramecium
parasite
pepsin
permeable membrane
petiole
pharynx
photosynthesis
plasma
prehension
proboscis
protein
protoplasm
ptyalin
pulmonary
reticulum
rickets
rumen
salivary gland
saprophyte
scurvy
spiracles
spirogyra
spleen
stomata
talons
tentacles
thoracic duct
tissue
tracheal tubes
trypsin
urea
vacuoles
ventricles
villi

II. Every organism begins life as a single cell.

1. The process of cell growth and reproduction is controlled by a great many factors both internal and external to the organism.

   (a) The processes of growth and assimilation change the non-living materials taken in by the organism into living material.

      (i) Protoplasm is the only substance which possesses the power of growth and assimilation.

   (b) The process of growth consists of any one or more of the following processes:

      (i) Assimilation of non-living substances and the production of new protoplasm from them.

      (ii) Increase in the size of the cell or cells.

      (iii) Increase in the number of cells.

      (iv) The development in higher organisms of different kinds of cells for special purposes.

   (c) There are five main stages in the growth of seeds into plants. These stages are:

      (i) The absorption of water.

      (ii) The beginning of respiration.

      (iii) The digestion of food materials.

      (iv) The transfer of digested food to the growing parts of the plant embryo.

      (v) Assimilation of soluble food material by the growing cells into new protoplasm and cells.

2. The life processes of both plants and animals are based upon the opposing forces of anabolism and katabolism.
   (a) As long as anabolism exceeds katabolism, growth continues.
3. Flowering plants may be classified into groups on the basis of the number of cotyledons which they produce.
   (a) The internal structure of the stems of monocotyledons and dicotyledons differs characteristically.
4. The adult stage of an organism results from growth and division of the single cell from which it originated.
   (a) Many animals undergo metamorphosis as they develop from the egg to the adult.
5. Normal growth is regulated by the proper functioning of all parts of an organism in the presence of certain essential materials and conditions.
   (a) The secretion of the endocrine glands has a regulating effect upon normal body growth.
   (b) Drugs interfere with or modify the normal functioning of various parts of the organism.
6. The body of an organism is a very delicately adjusted mechanism, the efficient functioning of which depends upon the proper coordination of all its parts.

Vocabulary Expansion Required for Generalization II

accretion
adventitious
anabolism
annual rings
assimilation
biennials
blastula
cambium layer
cartilage
cleavage
cortex
cotyledon
dicotyledon
differentiation
embryology
endocrine
endosperm
fibrous root
filament
germinal disc
gestation
hilum
hormone
hypocotyl
imago
internode
katabolism
lateral
metabolism
metamorphosis
micropyle
monocotyledon
narcotic
nymph
oviparous
parenchyma
phloem
pith
pituitary
pleurococcus
plumule
primary root
pupa
radicle
respiration
root cap
segmentation
sieve tube
senescence
tap root
terminal bud
thryoxine
vertebrate
viviparous
xylem

III. Life must come from life.

1. All methods of reproduction have as their purpose the generation of a new individual which will replace the old and dying, in order that the race may survive.

   (a) Parental care of the young tends to decrease the death rate.

2. Reproduction is essentially a kind of growth in which one part of the parent organism is detached

and grows into a new individual.

(a) The difference between sexual and asexual reproduction is essentially a difference in the way in which the detached portion of protoplasm, which grows into a new individual, is produced.

(i) All sexual methods of reproduction are similar in that they bring about a union of two cells or a part of two cells to form a single cell capable of producing a new individual which will inherit characteristics from both parents.

(ii) The extensive production of spores makes it difficult for man to get rid of certain types of injurious fungi.

3. As we pass upward in the scale of life, from the lower to the higher forms of animals, the power to replace lost parts is lessened.

4. All methods of reproduction are essentially alike in that they ultimately depend upon cell division.

5. In the simpler types of water plants distribution of the organism is brought about by the swimming sperm; but in land plants the sperms must be disseminated by other means.

(a) The essential organs of reproduction in the higher forms of plants are the stamens and pistils.

(b) Certain changes in the mode of reproduction have made the seed plant the dominant plant of our present environment.

6. Offspring have characteristics not exactly like the characteristics of either of the parents, and it is through these changes that variations in the structure and function of living things become possible.

   (a) The various devices for growth and reproduction which organisms have evolved have been the result of natural selection since inheritable variations which prove to be of advantage to an organism tend to survive.

   (b) As we pass from the lower to the higher scale of animal life, an increased specialization of cells for reproduction is found.

7. The period of infancy and dependency is longer among the higher animals than among the lower animals.

   (a) Parental care among the animals other than man is the result of instinct not reason.

      (i) Most insects provide for their young merely by depositing the eggs in a favorable place on or near a suitable food supply.

Vocabulary Expansion Required for Generalization III

anther
antheridium
anterior
archegonium
asexual
binary fission
budding
calyx
capsule
conjugation
cross pollination
fertilization
gamete
Ichneumon fly
ovary
ovules
ovum
pistilate
posterior
protonema
receptacle
regeneration
rejuvenation
rhyzome
sepal
septae
sperm
spontaneous generation
sporangium
stamen
staminate
style
tuber
variation
zygote

IV. Each habitat has its own set of living conditions

1. Fitness to the environment determines largely the type of organism which can survive in that environment.

2. The habitat of an animal may be inferred from the general appearance of the animal.

(a) The fitness of a living thing to live in a certain kind of environment is passed on from generation to generation.

(i) Some living things may change in structure and/or function when they are placed in a different type of habitat.

(1) Fitness of most organisms to a water habitat requires that the organism have

a body which can be prevented from sinking to the bottom since protoplasm is generally denser than water.

(ii) Water plants have a great variety of special characteristics which fit them to a water habitat.

(b) Since soil and air have different properties from water, a different set of conditions prevails in a land habitat, and these conditions have a characteristic effect upon the structure and function of the living things in it.

(i) Besides numerous devices used to prevent excessive evaporation from their tissues, land plants have root structures which assist the plant in obtaining water and food materials from the soil.

(ii) The transportation system of land plants is much more highly developed than that of water plants.

(iii) Land habitats differ according to the amount of water available in them for living plant and animal organisms.

(1) Plant structures are modified in many ways to adapt the plant to the available water in the land habitat.

a. Fitness to a water habitat requires

that the organism possess the ability to obtain oxygen and often the ability to keep from sinking to the bottom while in the water habitat.

3. Every animal is a bundle of adaptations to its particular environment.
   (a) Land animals must have structures which enable them to obtain oxygen from the air, to effect reasonably easy locomotion, and to bring about safely the reproduction of young.
   (b) In general all organisms are fitted to their environments, but often these organisms possess structures which are non-adaptive and appear to serve no useful purpose.
   (c) Should structures develop in an animal which are harmful to it, that species of animal will not likely survive.
4. Every wild animal has its natural enemies.
   (a) Many animals and plants have colors and color patterns which fuse with their usual environment and make them almost indistinguishable from their immediate surroundings.
   (b) Animals with conspicuous coloration are generally provided with special means of defence and are usually avoided by potential enemies.
   (c) Some animals lacking special organs of defence avoid enemies by the means of mimicry.

5. In the struggle for existence, those species which are best fitted to their environment tend to survive.
6. Paleontologists, using fossil records, have been able to build up a fairly complete picture of the history of the life on the earth since very early times.
   (a) Fossil records indicate that with the passage of time there was an increasing complexity and specialization of structure among certain groups of organisms; but these records show also that organisms abundant in one geological time often become extinct in some succeeding age.
   (b) When changes take place in any environment the organisms there must either adapt themselves to the new conditions, seek a more favorable environment, or perish.
      (i) Species which become too specialized to permit change in their structure or function usually perish because of their poor adaptability.
7. The relationship existing between living things in a given environment determines the kind and number of them which can exist there.
8. As a result of a tremendous over-production of living things, there is a competition among living things for the necessities of life.
9. The interdependency of living things is so complex

that any change in the number of a given kind of living thing brings about a change throughout the whole living world until a new balance is obtained.

10. Both geographic and topographic factors influence the distribution of plants and animals.

    (a) Where barriers did not exist, species developing in one region gradually spread to other favorable regions where they came into competition with other species and those most fitted for the struggle survived.

<u>Vocabulary Expansion Required for Generalization IV</u>

amphibian
bast
camouflage
diatoms
dinosaur
fossil
habitat
hydrophyte
marsupials
mesophyte
mimicry
paleontology
placental mammal
sedimentary
strata
topography
tracheids
xerophyte

V. Man has classified living things by grouping together those which are similar in shape, habitat, use, habits, or other characteristics because he has found that such systems of classification are of great value to him in learning to understand and control living things.

1. Modern classification of plants and animals is based chiefly upon similarities and differences of structure.

    (a) The closeness of relationship of organisms is

determined by the degree to which they resemble each other.

(b) Much evidence shows that the present forms of life have come about through modification of earlier ancestral forms.

2. The theory of evolution explains satisfactorily the fossil records, the resemblance in structure of many species, the facts of embryology, geographic distribution, and similar factual evidence.

Vocabulary Expansion Required for Generalization V

anatomy
Angiosperm
Annelida
antennules
arboreal
Arthropoda
bilateral symmetry
Bryophytes
cephalo-thorax
chitin
Chordata
Coelenterata
Coleoptera
Crustacea
Diptera
dorsal
Echinodermata
exoskeleton
facets
fronds
gametophyte
ganglion
genera
Gymnosperm
Hemiptera
herbaceous
homologous
Hymenoptera
Linnaean system
Lepidoptera
Malpighian tubes
maxillae
maxillipeds
Mollusca
Nemathelminthes
notochord
Orthoptera
ovipositor
phylum
Platyhelminthes
Porifera
protozoa
Pteridophytes
sinuses
somites
spermatophytes
swimmerets
Thallophytes
ventral

VI. By discovering the laws of nature which govern the life processes of organisms, man may use this knowledge to select and improve living things useful to him, or to eliminate injurious species.

1. The main problem of the farmer is to conserve or improve the temperature, fertility, moisture content, and other necessary soil conditions.
   (a) Certain kinds and amounts of foods are needed for each particular type of living thing.
2. Conservation of our forests, minerals, and wild life is essential from both the economic and recreational points of view.
3. By means of refrigeration, canning, preserving, or careful storage, the wastage of plant and animal products may now be reduced to a minimum.
4. Control of weeds and insect pests depends almost entirely upon a knowledge of their habits and development.
   (a) Community cooperation is essential for effective control of plant and animal pests.

<u>Vocabulary Expansion Required For Generalization VI</u>

ammonium phosphate	equine encephalomyelitis	mulch
antibodies	fermentation	nutritive ratio
bovine	filtrate	Paris Green
capillarity	green manure	"reactors"
cold frame	humus	rotation crops
conservation	immunity	silt
entomologist	inoculate	serum
		sodium fluoride

tankage tuberculin virus

VII. Natural law operates to preserve the characteristics of living things yet, at the same time, provides for the possibility of change.

1. By experimentation man has been able to discover some of the laws of heredity and has been successful in applying them to improve plants and animals for his own use.
   - (a) Observations of the many characteristics of living things reveal that no two individual living things are exactly alike.
   - (b) Since both parents contribute to the total number of characteristics of the offspring, there is thus secured the possibility of variation.
2. The chromosomes, thought to be the bearers of hereditary characters, vary in number among the different species of animals and plants.
   - (a) Certain changes in the chromosomes may give rise to mutations, and this probably accounts in part for the many species of plants and animals.
3. By regulating the materials and conditions of the environment, man may modify the living things of any generation, but these modifications are not inherited by the next generation.

4. Artificial selection and cross-breeding are the fundamental principles used in the modern production of new and improved varieties of useful animals, grains, vegetables, flowers, etc., but cuttings are used in the case of most trees and fruits.

   (a) Hybridization often produces offspring having increased vigor, but this increase lasts only for the one generation.

Vocabulary Expansion Required for Generalization VII

albino
artificial selection
biparental reproduction
chromosome
"crossing" strains
dominance
gene
grafting
hybrid
layering
mass selection
mixed breeding
mutations
pedigree registration
progeny performance
pure-bred
recessive character
Restricted Area Plan
scion
stock
Supervised Herd Plan
unit character
zoologist

Diagrams to be Learned

The student should learn to make reasonably accurate drawings or diagrams to illustrate the following:

1. an amoeba.
2. a paramecium.
3. the tap root system of dandelion, tree, etc.

4. the stages in the germination of a bean seedling.
5. the general features of a cross-section of a root.
6. the apparatus used to illustrate osmosis.
7. the stomates on a leaf.
8. the longitudinal structure of a dicotyledon (stem.)
9. the arrangement of fibro-vascular bundles in a celery stalk.
10. cross-sectional structure of a dicotyledon (stem.)
11. cross-sectional structure of a monocotyledon (stem.)
12. cross-section of a leaf.
13. the apparatus for electrolysis of water.
14. the typical forms of bacteria.
15. the main types of body cells.
16. a cross-section of a gland.
17. the position of the salivary glands.
18. the digestive tract of a chicken.
19. the longitudinal section of a hydra.
20. the cross-section of the villi.
21. the digestive tract of man.
22. the circulatory system of man.
23. the circulatory system of an insect.
24. the cross-section of the skin.
25. the structure of Spirogyra or Ulothrix.
26. cross-section of corn seed.
27. cross-section of a shoot with its bud.
28. external appearance of a rootlet and root cap.

29. the stages in the life cycle of a frog.

30. the stages in the metamorphosis of a fly, a mosquito, a bee, or a moth.

31. the stages in the metamorphosis of a grasshopper.

32. cross-section of a typical "complete" flower.

33. the stages in the fission of amoeba, and paramecium.

34. the general structure of blue mold (any typical mold).

35. the process of fertilization of a flower.

36. the beaks of various classes of birds, based on food habits.

37. the feet of various classes of birds, based on food habits.

38. the carbon-oxygen cycle.

39. the nitrogen cycle.

40. the external features of a grasshopper.

41. the mouth parts of a grasshopper.

42. the general features of the internal structure of a grasshopper.

43. the general features of the internal structure of a crayfish.

44. the stages of growth in the life cycle of Marchantia.

45. the general structure of a fern plant.

46. the cross-sectional view of a hot-bed.

47. the various types of grafts.

48. the various methods of budding.

Experiments and Activities to be Performed

The student should:

1. discover and identify amoeba in pond water or culture.
2. discover and identify paramecium in water.
3. obtain examples of, and distinguish the main types of, root systems.
4. observe the stages in the germination of a seed, and the growth of a seedling.
5. prepare and examine a cross-section of a root.
6. demonstrate the process of osmosis.
7. show the presence of dissolved substances in soil water.
8. observe the stomata on a leaf, using a microscope.
9. examine the longitudinal and cross-sectional structure of fibro-vascular bundles of a stem.
10. examine a cross-section of a dicotyledon (stem.)
11. examine a longitudinal section of a dicotyledon (stem.)
12. examine a cross-section of a monocotyledon (stem.)
13. examine a longitudinal section of a monocotyledon (stem.)
14. examine slides showing the various kinds of bacteria.
15. observe cells of human blood, frog blood, etc.
16. observe from slides other types of body cells.
17. show the action of saliva on starch, and of pepsin in the digestion of proteins.
18. examine a slide showing glandular tissue.
19. show that salivation may be stimulated by the sight, smell, or taste of food.

20. examine the digestive tract of a bird.

21. examine the digestive tract of a mammal.

22. observe with the microscope the circulation of blood in live tissue, as in the web of a frog's foot.

23. observe a longitudinal section of hydra.

24. observe a cross-section of intestinal wall which shows the villi.

25. observe the structure of the gills of a fish.

26. observe the tracheal tubes of an insect.

27. find and recognize lenticels in the bark of a plant.

28. identify CO_2 gas from a number of given colorless gases.

29. prove that plants give off CO_2 gas.

30. examine a microscopic slide showing a cross-section of the skin.

31. produce crystallization of various substances from their solutions.

32. observe yeast cells reproduce by budding.

33. discover and identify Spirogyra, Ulothrix, Pleurococcus, etc.

34. examine a slide showing the cross-section of a seed of corn.

35. examine a bean and a corn seedling to see root hairs, cotyledons, and early stages of growth.

36. prove that seeds must respire in order to germinate and continue growth.

37. observe a longitudinal section of a bud.

38. examine an onion root to see the root tip, root cap, and root hairs.

39. collect and hatch some frogs' eggs in an aquarium, observing the stages in the life cycle of the frog.

40. collect eggs of moths or butterflies and care for these until the insect's life cycle is completed.

41. hatch grasshopper eggs and watch the life cycle of the insect while kept in a terrarium.

42. obtain larvae of mosquitoes during spring months and observe the completion of the life cycle.

43. examine and identify the parts of various "complete" and of various "incomplete" flowers.

44. examine slides showing fission of amoeba and of paramecium.

45. make a microscopic examination of a mold.

46. show that various plants may grow from cuttings.

47. observe a cross-sectional cutting of an onion or lily bulb.

48. obtain samples of plants exhibiting various methods of seed dispersal.

49. observe the brood of the honey bee or wasp.

50. using larvae of cabbage white butterfly, watch the life cycle of a parasite, the Ichneumon fly.

51. demonstrate "variation" in leaves, pods, fruits, etc., of at least one variety of plant.

52. determine the buoyant force of various fluids on various solids.

53. discover and make diagrams of some types of diatoms found in pond water.

54. prepare and populate a desert terrarium.

55. demonstrate types of protective coloration.

56. obtain some specimens of fossils from rock, coal, or sandstone, etc.

57. dissect a grasshopper and identify the chief organs.

58. obtain at least one specimen of the different orders of insects.

59. identify from specimens the various parts of the liverwort, Marchantia.

60. observe with a microscope the spores, sori, fronds, etc. of the fern.

61. examine the structure and seed of a pine cone.

62. determine experimentally the differences in soils as to water-holding capacity, organic content, texture, amount of air etc.

63. demonstrate the effects of different amounts of water on the growth of plants.

64. demonstrate the principle of capillarity.

65. show the effect of a soil mulch in conserving moisture.

66. show that wet soils are colder than dry soils.

67. obtain root systems of leguminous plants and examine the nodules.

68. collect samples to demonstrate the effect of sawfly on wheat.

69. attempt to make a successful graft or budding experiment.

CHAPTER IV

DATA FOR CHEMISTRY I

Generalizations

I. Matter is subject to two main types of change--physical change and chemical change.

1. There are three physical states of matter known as solid, liquid, and gas.

   (a) A change in the physical state of a substance does not involve any change in the composition of the substance.

   (i) The properties of the components of a mixture remain unchanged.

2. Any chemical change in matter brings about a change in the composition and properties of the matter, producing a different substance or substances.

   (a) Chemical reactions may be brought about by any energy change which results in combination, decomposition, displacement, exchange, or molecular rearrangement of reacting substances.

   (b) Each pure substance resulting from a chemical change manifests a specific set of characteristic properties which is always the same for the same pure substance under the same conditions.

   (i) Substances are identified by means of their

distinctive physical or chemical properties.

(ii) Elements are substances which have not been decomposed into simpler substances.

(iii) Compounds are substances that can be decomposed into two or more simpler substances.

(iv) A given compound, whatever its origin, always contains the same elements in the same proportion by weight.

(v) The ingredients of a solution are homogeneously distributed through each other.

3. In physical and chemical changes matter is neither created nor destroyed.

(a) The total weight of substances formed in a chemical reaction is exactly equal to the weight of all the substances which entered into the change.

<u>Vocabulary Expansion Required for Generalization I</u>

alchemy
anode
atomic theory
catalyst
cathode
combustion
electrolysis
oxidation
Fahrenheit
filtration
homogeneous
philosopher's stone
phlogiston theory
synthesis

<u>Terms Requiring Formal Definition</u>

alloy
chemical change
chemical compound
combustion
density
element
matter
metal
mixture
non-metal
oxide
physical change

Laws Requiring Formal Memorization

1. Law of Conservation of Matter.
2. Law of Definite Composition.

II. When substances burn in air or in oxygen, oxides are formed.

1. The products of combustion are always heavier than the weight of the substances burned.
2. Raising the temperature in most chemical processes hastens the reaction.
   (a) Molecular motion ceases at absolute zero.
   (b) By means of a catalyst many chemical processes may be hastened.
   (c) Substances which burn in air burn faster and with greater brilliance in oxygen.
3. The kindling point of a substance may be lowered by increasing the surface exposed to chemical action, by increasing the pressure, or by using a catalyst.
4. All methods of extinguishing fires depend either upon cooling the combustible material, or upon keeping out the air so that oxygen is no longer available for the process of oxidation.
5. Allotropic forms of the same element may be formed either by absorption or by the release of energy.

Vocabulary Expansion Required for Generalization II

allotropic
bleaching agent
kindling point
spontaneous combustion

III. Hydrogen compounds are among the most important, numerous, and widely distributed substances in nature.

1. Hydrogen may be prepared from many compounds either by the process of replacement or by decomposition.
   (a) Only those metals above hydrogen in the replacement series will replace hydrogen from dilute hydrochloric and sulphuric acids.
   (b) Reduction and oxidation occur simultaneously and are quantitatively equal.
2. Water is the most important of all the hydrogen compounds since it is such a universal catalyst that without it life of any sort would be impossible.
3. The kinetic-molecular theory assumes that a gas is a vacant space with exceedingly minute particles scattered throughout, and that these particles under ordinary conditions are flying about in all directions with great speed.
   (a) All gases have the power of diffusion.

Vocabulary Expansion Required for Generalization III

diffusion
displacement
hydroxide
hydrogenation
kinetic-molecular theory
oxyhydrogen flame
reduction
replacement series
support combustion

Terms Requiring Formal Definition

calorie
reduction

IV. Water is so universally distributed that it has been used in determining many scientific standards such as the temperature scales, units of: weight, density, heat, and volume.

1. Since no other substance has precisely the same boiling point or freezing point as water, these two temperatures are used in identifying water.
2. Solution = solvent + solute.
   (a) Any substance that will dissolve in water will cause the resulting solution to boil at a higher temperature and to freeze at a lower temperature than that at which pure water boils or freezes.
   (b) The boiling point of any solution becomes lower as the pressure is decreased and higher as the pressure is increased.
   (c) The solubility of solutes is affected by heat,

pressure, and the nature of the solvent and the solute.

3. Hydrogen and oxygen combine in one definite proportion by weight to form water, and in another definite proportion by weight to form hydrogen peroxide.

__Vocabulary Expansion Required for Generalization IV__

distillation
eudiometer
qualitative analysis
quantitative analysis
saturated solution
solute
solvent

__Terms Requiring Formal Definition__

atom
heat of fusion
heat of vaporization
molecule
specific heat

__Laws Requiring Formal Memorization__

1. Gay Lussac's Law of Volumes.
2. Law of Multiple Proportions.

V. All matter is composed of atoms.

1. An atom is the smallest part of an element which can take part in a chemical reaction.

(a) The atoms of a given element are unvarying in average mass but are different in average mass

from the atoms of other elements.

(i) Some elements are composed of several kinds of atoms which differ only in their relative mass. These different varieties of the same element are known as isotopes of the element.

(ii) The atomic weight of an element is the weight of its atom as compared with the weight of one atom of oxygen taken as 16.

2. In most common elementary gases such as oxygen, nitrogen, and hydrogen, each molecule is composed of two like atoms held together in chemical combination.

3. In a compound, the molecule is composed of two or more atoms of different elements held together in chemical combination.

   (a) Each molecule of any given compound is identical with every other molecule of that compound, but different from the molecules of other compounds.

   (i) A molecule is the smallest particle of an element or compound which can normally lead a separate existence.

4. The sum of the weights of the atoms of substances which take part in a chemical reaction must equal the sum of the weights of the atoms in the products of the reaction.

5. The volumes of gases used and produced in any chemical reaction can always be represented by the ratio

of simple whole numbers.

6. When any two elements A and B combine to form more than one compound, the weights of B which unite with a fixed weight of A are in the ratio of small whole numbers.

<u>Vocabulary Expansion Required for Generalization V</u>

dioxide
isotope
monoxide
monatomic molecule

<u>Terms requiring Formal Definition</u>

hypothesis
law
theory

VI. Formulae and equations represent experimental facts about the nature of certain real substances.

1. The symbol of an element means not only one atom of the element but also the gram-atomic weight of the element.
2. The valence of any element is that number of atoms of hydrogen with which one atom of the element will combine.
3. Certain groups of elements may react chemically like a single element.
4. Chemical reactions may take place through direct syn-

thesis, simple decomposition, substitution, or double decomposition.

5. In any chemical equation the relative weights of the reacting substances are shown.
   (a) The atomic weight of any element is equal to its combining weight or to some multiple of it.
   (b) Each element except those entirely inert has a definite combining weight.
6. For any element, its atomic weight multiplied by its specific heat is equal to 6.4 approximately.

Vocabulary Expansion Required for Generalization VI

alkalies
base
binary compound
by-product
Dakin's solution
divalent
double decomposition
fused hydroxide
indicator
nascent
radical
replacement
replacement series
simple decomposition

prefixes: uni-
mono-
di-
bi-
tri-
tetra-
quadri-
penta-
hypo-
per-

suffixes: -ic
-ous
-ate

Terms Requiring Formal Definition

acid
atomic weight
base
gram atomic weight
gram molecular weight
hypothesis
law
molecular weight
precipitate
salt
theory
valence

VII. The exchange of the negative and positive ions of acids and bases results in the formation of water and a salt.

1. All acids contain hydrogen.
2. Acids have a sharp, sour taste, and turn the dye litmus from blue to red.
3. Aqueous solutions of bases have a bitter taste, a soapy feeling; and change red litmus to blue.
4. All bases contain the hydroxyl radical.
5. When a solution of an acid and of a base are brought together in the right proportions, the characteristic properties of each disappear.
    (b) The volumes of basic or acidic solutions required for neutralization vary inversely as the concentration of the reacting solutions:

    $$(V_1 \times N_1 = V_2 \times N_2)$$

    (i) Any "normal" solution of an acid contains one gram of replaceable hydrogen per litre of solution.

    (ii) Any "normal" solution of a basic solution contains 17 grams of the hydroxyl group per litre of the solution.
6. The lowering of the freezing point and the raising of the boiling point depend directly upon the number of molecules of solute present in a given weight of solvent.
7. Electrolytes (acids, bases, and salts) when dissolved

in a solvent such as water, or heated to a molten state, undergo dissociation into a number of oppositely electrically charged particles (ions) capable of conducting an electric current.

(a) The activity of an acid or base is due to the degree of ionization of the compound when in solution or in a molten state.

(i) The nature and relative amount of the solvent, the presence of other ions, temperature, and light may affect the degree of ionization.

(ii) Positive and negative ions unite to form neutral molecules.

8. Electrolysis involves the discharge of the positive and negative ions at their respective electrodes, with resulting chemical changes.

(a) When acids are dissolved in water they form hydrogen ions, while bases form hydroxyl ions.

(i) The characteristics of acids are really peculiarities of the hydrogen ion.

(ii) Strong acids or bases are almost completely dissociated in dilute solutions; weak acids or bases are only slightly dissociated in solution.

(b) In general, all chemical reactions of acids, bases, and salts in dilute solutions are reactions between ions.

9. Chemical reactions always involve an energy change.

   (a) Compounds having very high heats of formation are very stable and are easily formed by direct combination; those compounds with low heats of formation are unstable; while those with negative heats of formation may be so unstable as to be explosive.

<u>Vocabulary Expansion Required for Generalization VII</u>

acid salt	heat of formation
end point	neutralization
endothermic reaction	ternary acid
exothermic reaction	titration

<u>Terms Requiring Formal Definition</u>

electron
ion
molar solution
a "normal" solution of an acid
a "normal" solution of a base

VIII. All matter is electrical in nature since every atom has a positively charged nucleus surrounded by enough electrons to make the atom as a whole neutral.

1. Atoms of different elements differ from one another in the number and arrangement of the electrons and protons of which they are made.

   (a) Almost the entire weight of an atom is concentrated in a nucleus which consists of protons,

neutrons, and electrons, around which more electrons revolve at high speed in definite orbits.

2. Ordinary chemical reactions involve either a transfer or a sharing of the outer electrons of atoms.
   (a) The valence of any element is determined by the number of electrons which its atom must gain or lose in order to complete its outer shell.
      (i) In metals the electrons in the outer shell are held very loosely and may be readily removed from the atom. In non-metals these outer shell electrons are held very firmly and the atom has even a strong tendency to gain electrons to complete the outer shell.
      (ii) The ions of a compound are held together by the electrical attraction of unlike charges.
      (iii) The tendency of atoms to complete the outer shell by gaining or losing electrons determines the chemical activity of the elements.
3. The algebraic sum of the total charges of the ions which form an electrically neutral molecule must be zero.

Vocabulary Expansion Required for Generalization VIII

electron
neutron
nuclear atom
polar compound

Terms Requiring Formal Definition

non-metal
metal
valence

IX. The soluble oxides of non-metals form acids when dissolved in water; soluble oxides of metals form bases when dissolved in water.

1. Sulphuric acid is needed either directly or indirectly in almost every major industry.
2. The oxidation of carbon compounds is one of the essential processes of life and produces CO_2 as a by-product of the process.
   (a) Carbon dioxide is used by all green plants during the process of photosynthesis.
3. Most common acids will react with calcium carbonate to produce a salt and release carbon dioxide gas.

Vocabulary Expansion Required for Generalization IX.

acid anhydride
amorphous
amphoteric
anthracite
acquadag
basic anhydride
bisulphite
Duprene
effervescence
foamite

fuming sulphuric acid	dibasic
graphite	dry ice
green vitriol	lead chamber process
hopcalite mask	monobasic
blue vitriol	monoclinic
carbonated water	oleum
choke damp	plumbago
contact process	polymerization
dehydration	reversible reaction
destructive distillation	

X. Though most gases may differ greatly in chemical properties, they show great uniformity in many physical properties.

1. All gases, and most liquids and solids, expand with an increase of temperature and contract with a decrease of temperature.
2. The volume of a mass of gas varies inversely as the pressure when temperature remains constant.
   (a) Every gas has its own critical temperature.
3. When any gas is compressed it liberates heat; when it expands is absorbs heat.
   (a) Many gases including air are liquified by subjecting them to the combined effects of high pressure and low temperature.
4. The volumes of gases used and produced in a chemical change can always be represented by a ratio of small whole numbers.
5. Equal volumes of gases under the same conditions of temperature and pressure contain the same number of molecules.

6. The gram-molecular weight of any gas at N.T.P. occupies a volume of 22.4 litres.

Vocabulary Expansion Required for Generalization X

combining weight
qualitative analysis
quantitative analysis

Laws, etc., Requiring Formal Memorization

Avogadro's hypothesis
Boyle's Law
Charles' Law
Dulong and Petit's Law
Gay Lussac's Law
Law of Equivalent Weights

XI. Many of the compounds of nitrogen are essential for the life processes of plants and animals.

1. Any method whereby free nitrogen can be made to combine with other elements to form compounds of commercial value are regarded as nitrogen fixation reactions.

2. Many ammonium salts are readily decomposed by heat.

(a) In some chemical reactions both the formation and the decomposition of a compound proceed at the same time and in such a way that under certain conditions a kinetic equilibrium may be produced.

(b) Catalysts may reduce the time required for a reaction to come to equilibrium, but they do not

change the composition of the equilibrium mixture.

(c) The speed of a chemical action depends upon the concentration of the reacting substances.

(d) The condition of any chemical equilibrium is dependent upon the temperature of the reacting mixture.

3. Most explosives are chemical reactions in which enormous amounts of hot gases are rapidly formed, producing very great pressure.

   (a) Most modern explosives depend upon nitric acid for their manufacture.

4. Only leguminous plants are able to produce nitrogen compounds from free nitrogen.

Vocabulary Expansion Required for Generalization XI

aqua fortis
aqua regia
caliche
carbon dioxide cycle
critical temperature
detonation
Dewar flask
kinetic equilibrium
laughing gas
metastable
neon gas
niter
nitrogen cycle
nitrogen fixation
oil of vitriol
photosynthesis
relative humidity
sal ammoniac
stratosphere
troposphere

Laws Requiring Formal Memorization

Law of Molecular Concentration
Law of Mass Action

<u>Chemical Tests to be Memorized</u>

Test for: water
oxygen
hydrogen
a chloride
a nitrate
a sulphate
a sulphite
a sulphide
a carbonate
a base
an acid
chlorine gas
carbon dioxide gas
carbon monoxide gas
an ammonium salt
nitrogen dioxide
nitric oxide

Diagrams to be Learned and Activities

to be Performed

The student should:

1. prepare oxygen from $KClO_3$.
2. prepare oxygen from Na_2O_2.
3. apply various tests for oxygen.
4. prepare ozone.
5. produce allotropic forms of sulphur.
6. prepare hydrogen gas from acids on metals.
7. obtain hydrogen gas from steam.
8. show the reducing power of hydrogen gas.
9. apply tests for hydrogen gas.
10. determine the volumetric composition of water.

11. produce water by synthesis of H_2 and O_2.

12. electrolyse brine solution.

13. learn the diagram for the Vorce cell.

14. learn the diagram of the apparatus used to produce metallic sodium.

15. prepare chlorine gas.

16. bleach a variety of colored substances using moist chlorine gas.

17. prepare HCl gas.

18. show the effect of sunlight on H_2O and Cl_2 solutions.

19. apply the test for a chloride.

20. show synthesis of HCl from H_2 and Cl_2.

21. electrolyse hydrochloric acid.

22. demonstrate the process of neutralization.

23. learn the correct procedure in titration.

24. prepare H_2S gas.

25. show the effect of H_2S gas on solutions of various metallic salts.

26. prepare some CS_2 as a liquid.

27. prepare SO_2 gas.

28. use SO_2 gas as a bleaching agent.

29. prepare SO_3 gas by the contact method; make H_2SO_4 solution.

30. apply the test for a sulphide.

31. apply the test for a sulphite.

32. apply the test for sulphates.

33. learn the diagram of the lead chamber apparatus used to manufacture H_2SO_4.

34. learn the diagram of the apparatus used for commercial production of coal gas.

35. charge and set into operation a soda-acid fire extinguisher

36. prepare CO_2 gas from acid + carbonate.

37. apply the test for CO_2 gas.

38. apply the test for any carbonate.

39. prepare CO gas from formic acid.

40. show the reducing power of carbon and CO gas.

41. apply the tests for acids using various indicators.

42. apply the tests for a basic solution using various indicators.

43. learn the diagram of the liquid air machine.

44. prepare ammonia gas.

45. show that ammonia is composed only of hydrogen and nitrogen.

46. illustrate the extreme solubility of ammonia in cold water.

47. learn the diagram of the ice-making machine.

48. learn the diagram of the Haber process for making ammonia.

49. prepare nitric acid from a nitrate.

50. learn the diagram of a commercial method of making nitric acid.

51. learn the diagram of Ostwald's system of oxidizing ammonia.

52. decompose nitric acid by heat.

53. prepare NO gas (nitric oxide gas).

54. apply the test for a nitrate.

55. prepare N_2O gas.

56. apply the test for ammonium salts.

57. apply the test for NO gas (nitric oxide gas).

58. apply the test for NO_2 gas.

CHAPTER V

DATA FOR PHYSICS I

Generalizations

1. Modern civilization is largely the product of man's knowledge and control of matter and its composition.

   1. The smallest particle into which matter can be divided without destroying its characteristic properties is the molecule.

      (a) The atom is a complex structure composed of a relatively heavy nucleus of electrically charged particles surrounded by minute electrons travelling in orbits at high speed.

   2. Matter can exist in three states: solid, liquid, gas.

      (a) Solids have definite volume and shape; liquids have definite volume but they take the shape of the containing vessel; gases have neither a definite volume nor a definite shape.

      (b) Any gas may expand indefinitely to fill the entire space containing it, no matter what the volume.

      (c) In solids the molecules cling together very firmly and do not easily change their relative positions;

in liquids the attraction between the molecules is less and they slide over one another easily; but in gases the molecules move so freely that they separate and expand indefinitely.

3. An increase in temperature increases the molecular motion of a substance and promotes fluidity, converting a solid substance into a liquid and finally into a vapor.

4. Matter cannot be created or destroyed.

   (a) All changes occurring in matter are either physical changes or chemical changes.

      (i) If the identity of a substance is not lost during a change in matter, the change is physical; if a new substance with new characteristic properties is formed, the change is chemical.

         (1) We identify substances by studying their special properties.

   (b) The quantity of matter which a given body contains is its mass, and this mass does not vary.

      (i) The weight of any body depends upon the mass or quantity of matter it contains, and upon the measure of the earth's attraction for it.

   (c) Matter is impenetrable, hence no two objects can occupy the same space at the same time.

      (i) All matter is more or less porous,

(d) All matter has the property of inertia, hence bodies at rest tend to remain at rest; those in motion tend to remain in motion.

5. Substances differ greatly in such properties as tensile strength, ductility, malleability, hardness, and brittleness.
6. From the units of length, mass, and time, all other units of measurement have been derived.

   (a) The C.G.S., or metric system of measurement, is a decimal system based on natural standards.

   (b) The F.P.S., or British system, being based chiefly on arbitrarily chosen standards, is cumbersome and ill-suited to scientific work.
7. The weight of a unit volume of any given substance is called its density. $D = W/V$.

<u>Vocabulary Expansion Required for Generalization I</u>

anneal
atom
brittleness
calibration
ductility
electron
energy
fluid
gravity
hardness
heterogeneous
impenetrability
inertia
mass
malleability
meter
mobile
nucleus
proton
quartz
tenacity
tensile strength
viscous
prefixes: deci-
centi-
milli-
deca-
hecta-
kilo-

Words and Terms Requiring Formal Definition

atom	liter
chemical change	matter
density	mean solar second
energy	molecule
gram	theory

Laws to be Memorized

Law of the Conservation of Matter.

II. Pressure applied anywhere to a body of confined or enclosed fluid is transmitted with undiminished force in every direction. The pressure acts at right angles to every portion of the surface of the container with equal force upon equal surfaces.

1. The pressure of a liquid increases in direct proportion to the depth and the density of the liquid.

$$p = hd$$

2. Liquid pressure is independent of direction and of the area or shape of the container.
3. Water seeks its own level.
4. A body while immersed in a fluid loses as much weight as the fluid it displaces.
   (a) If a body, when submerged in a fluid, displaces a weight of fluid greater than its own weight, it will rise and float with a part of its volume above the surface; but if it displaces a weight

of fluid less than its own weight, it will sink.

(b) Any liquid or solid substance is usually compared in weight to the weight of an equal volume of water in order to determine the specific weight of the substance.

Vocabulary Expansion Required for Generalization II

acidimeter
"acting force"
alcoholometer
alloy
artesian well
buoyancy
concentration
density
direct proportion
displace
equilibrium
flotation
hydraulic
hydrometer
hydrostatic pressure
inverse proportion
lactometer
manometer
mechanical advantage
pycnometer
resisting force
specific gravity
specific weight

Words and Terms Requiring Formal Definition

buoyancy
mechanical advantage
specific weight

Laws to be Memorized

Archimedes' Law
Pascal's Principle
The three laws of liquid pressure
The three laws of flotation.

III. Since air and other gases are fluid and have weight the laws of liquid pressure also apply to them.

1. The specific weight of any gas may be obtained by

comparing the weight of a given volume of it with the weight of an equal volume of air. Sometimes hydrogen instead of air is used as the standard for comparison.

(a) Dry air is always denser than moist air.

(i) Barometers aid in forecasting weather conditions.

2. Winds blow toward centres of low pressure areas; but the rotation of the earth on its axis deflects them from their courses producing the rotatory motion characteristic of cyclones and anticyclones.

   (a) Cyclones are generally accompanied by cloudy weather, precipitation, and higher temperature, but anticyclones by fair weather and lower temperature.

3. Both the temperature and the density of the atmosphere decrease as altitude increases.

4. The volume of any dry gas varies inversely as the pressure sustained by it when temperature is kept constant. Hence, PV = constant.

   (a) The density of a gas increases in direct proportion to the pressure sustained.

5. Both air compressor and air exhaustion pumps have many uses in modern industry.

6. Many types of water pumps depend upon air pressure for their operation.

(a) All types of siphons depend upon air pressure for successful operation.

Vocabulary Expansion Required for Generalization III

absolute pressure	cyclone
altimeter	dehydrate
aneroid	helium
anticyclone	isobar
aspirator	isotherm
atomizer	Magdeburg Hemispheres
barograph	standard pressure
caisson	standard temperature
compressibility	terrain clearance indicator
Cartesian diver	troposphere

Laws to be Memorized

Boyle's Law.

IV. The rate and nature of molecular motion depends upon the nature of the substance, its state, and its temperature.

1. All devices which use compressed gases utilize the energy of molecular motion.

   (a) Because of their rapid molecular motion, gases diffuse or intermingle without regard to weight, except that the lighter molecules diffuse more rapidly through a porous substance than heavy molecules do.

   (i) Without osmosis, plant and animal life would cease to exist.

(l) Osmosis or diffusion takes place in both directions through a porous wall, but the greater flow is normally from the less dense to the more dense solution.

2. All liquids evaporate more rapidly in a vacuum than when in air or under pressure.
3. The evaporation and the diffusion of solids furnish evidence that their molecules are in motion.
4. The state of any mass of matter depends upon the balance between the molecular forces and the molecular velocities of the matter.
   (a) The tenacity, ductility, hardness, elasticity, etc., of a substance depends upon the cohesion of its molecules.
      (i) Every material has a certain range of perfect elasticity through which it may be distorted before its elastic limit is reached.
         (l) Liquids are perfectly elastic and have a high elastic constant; gases also are perfectly elastic but have a low elastic constant.
      (ii) The angle of rebound is always equal to the angle of incidence when a perfectly elastic body strikes a hard surface.
      (iii) Within the limits of perfect elasticity, the elastic constant of any substance equals the

stress divided by the strain.

(iv) All liquids behave as if a thin elastic film were stretched over their surfaces, even though the force of cohesion varies in different liquids.

(b) The molecular force of adhesion causes liquids to rise in capillary tubes if the liquids wet them; but liquids which do not wet the capillary tubes are depressed.

(i) The amount of elevation or depression of a liquid in a capillary tube is inversely proportional to the diameter of the tube, and decreases with increase in the temperature of the liquids.

(ii) One substance dissolves in another if the force of adhesion between the molecules of solvent and solute is greater than the force of cohesion between the molecules of the solute.

(1) Both solids and liquids tend to lower the freezing point of a solvent when they dissolve in it.

(2) The solubility of solid substances usually increases as the temperature increases; but the solubility of most gases decreases with increased temperature of the solvent.

(3) Cooling a solution or evaporating some of the solvent may cause some of the solute to precipitate in the form of crystals, the shape and size of which depend upon the solute and the conditions under which crystallization occurs.

(4) The amount of gas which can be absorbed or dissolved by a liquid is directly proportional to the pressure.

Vocabulary Expansion Required for Generalization IV

absorption
adhesion
adsorption
ammonia
angle of incidence
Brownian movement
capillarity
cohesion
contractile
crystallization
diffusion
dry farming
elasticity
elastic constant
elastic limit
emulsion
evaporate
flexion
flexure
free liquid
Fuller's earth
graphite
hydrogen chloride
impregnate
kinetic
meniscus
miscible
olfactory
osmosis
safety factor
solubility
solute
solvent
strain
stress
surface tension
torsion
ultramicroscope
viscosity

Words and Terms Requiring Formal Definition

molecule
standard temperature and pressure (S.T.P.)

<u>Laws to be Memorized</u>

Henry's Law
Hooke's Law
Law of Capillarity

V. One of the greatest achievements of man is his knowledge, use, and control of heat energy.

1. Heat energy is a form of energy produced by the vibration or oscillation of molecules or of the electrons in the molecules of matter.
2. Heat may cause a substance to expand or contract, increase its temperature, or change its state.
3. Heat energy may be transformed into or produced from mechanical energy, chemical energy, radiant energy, and electrical energy.
4. The chief sources of heat are: the sun, the interior of the earth, friction, chemical action, impact, and compression.
   (a) Our chief source of artificial heat is chemical action.
5. The heat of any body depends upon the sum total of all the kinetic energies of its molecules; but the temperature of a body depends upon the average kinetic energy of its molecules.
6. Specially designed instruments must be used to measure extreme temperatures and to produce automatic records of temperature changes.

7. The total increase in the length of a solid when heated must be equal to its length times its change in temperature times its coefficient of linear expansion.
   (a) Solids expand in all directions when heated, hence for the same change in temperature the coefficient of expansion in area is approximately twice the coefficient of linear expansion, and the coefficient of cubical expansion is three times the coefficient of linear expansion.
   (b) Unequal heating causes many substances to crack or break.
   (c) Since changes in temperature affect the rate of oscillation of pendulums, chronometer balance, wheels, etc., some compensating device must be used in the construction of accurate chronometers.
8. An increase in temperature causes most liquids to expand.
   (a) Liquids have a higher coefficient of expansion than solids, and each liquid has its own characteristic expansion curve.
9. The coefficient of expansion of all gases is the same and the expansion is uniform at all temperatures.
   (a) If the pressure remains constant, the volume of any given mass of gas varies directly as the absolute temperature.

Vocabulary Expansion Required for Generalization V

absolute temperature
bimetal
bore
centigrade
clinical
coefficient of expansion
compensated pendulum
compound bar
constriction
corrugated
cryogenic
elinvar
Fahrenheit
fixed points of scale
impact
invar
maximum thermometer
minimum thermometer
nullify
oscillation period
spall
specific volume
superficial expansion
thermo-couple
thermometry
thermograph
thermostat
thermometer conversion
zero volume

Laws to be Memorized

Charles' Law
The gas law: $VP/T = V^1P^1/T^1$

VI. Sound is a form of energy produced by vibrating matter and can be transmitted only by wave motion in a material medium.

1. All sound vibrations are either transverse or longitudinal in character.
2. Sound waves travel at different rates of speed, depending upon the nature and condition of the media transmitting them.
   (a) For all types of wave motion the velocity equals the number of vibrations per second, times the wave length. Thus: $v = nl$.

3. Sound waves normally spread out in all directions.
4. All sound waves will reflect from suitable surfaces, producing an echo which is a reflected sound wave of undiminished velocity.
5. Sounds differ from one another in loudness, intensity, and pitch.
   (a) The intensity of sound is increased either by increasing the amplitude of the vibrations or the area of the vibrating body, or by increasing both amplitude and area.
   (b) The loudness of sound is inversely proportional to the square of the distance from the source, and depends upon the nature of the medium through which the sound travels.
   (c) The pitch of a note depends upon the number of vibrations or pulses per second, but is independent ofloudness and quality.
6. The natural vibration rate of a body depends upon the length, thickness, and material constitution of the vibrating body.
   (a) Sympathetic vibration occurs when the natural vibration rates of two objects are the same, or when the vibration rate of one of them is a multiple of the other.
7. When the condensation of one sound wave meets the rarefaction of another identical sound wave, silence is produced.

(a) Sound waves may interfere with one another in such a way as to cause beats.

Vocabulary Expansion Required for Generalization VI

acoustic	megaphone
amplification	rarefaction
auditory	refraction
beats	resonator
composite curve	resultant
concentric	sound ranging
condensation	sound reflector
decibel	stethoscope
Doppler's Principle	sympathetic vibration
forced vibration	transverse
intensity	ultra-sonic waves
interference	whispering gallery
longitudinal	

VII. Sound may occur in irregular vibrations producing noise, or in regular patterns to produce music.

1. Discord and harmony are both phenomena of beats.
2. Notes above or below certain frequency limits are inaudible to human beings.
3. A body may vibrate as a whole and in parts at the same time.
4. The quality of a sound depends upon the number of overtones present and upon their prominence.
5. The vibration rate of strings varies with the length, diameter, density, and tension of the vibrating string.
   (a) The vibration rate of a string is inversely proportional to its length, other factors constant.

(b) The vibration rate of a string is inversely proportional to its diameter, other factors constant.

(c) The vibration rate of a string is directly proportional to the square root of the tension on the string.

(d) The frequency of a vibrating string is inversely proportional to the square root of its density, other factors constant.

6. The pitch of a pipe varies inversely as its length.

(a) Any closed organ pipe produces a note whose wave length is four times as long as the pipe itself; while any open pipe produces a sound wave twice the length of the open pipe.

7. In many wind instruments a vibrating air jet is the source of the sound.

8. Vibrating plates, bells, etc., produce notes which are not whole number multiples of the fundamentals; and it is quite impossible to have such objects produce harmony by simultaneous vibrations.

9. Many devices such as the manometric flame, the Helmholtz resonators, the phonodeik, and the oscillograph are used to analyse sounds graphically.

Vocabulary Expansion Required for Generalization VII

anti-node
audio-frequency
audibility limits
chromatic semi-tones
chromatic scale
diatonic scale
dictaphone
discordant
ediphone
electromagnetic recorder
fundamental note
harmonic
international pitch
intervals
larynx
ligamentous
manometric flame
major chord
major triad
node
octaves
orthophonic
oscillograph
overtones
phonodeik
photomicrograph
radio frequency
semi-tone
sonometer
stylus
tempered scale
timbre
vibrograph

Words and Terms Requiring Formal Definition

overtone
harmonic
quality
timbre

Laws to be Memorized

Law of length for vibrating strings.
Law of diameter for vibrating strings.
Law of tension for vibrating strings.
Law of densities for vibrating strings.
Law of open and closed pipes.

VIII. Ether waves of certain lengths affect the optic nerve to produce the sensation called light.

1. Light waves resemble sound waves in some respects, but differ greatly in many other respects.

2. Though most of our natural light comes from the sun, light may also be produced artificially in many ways.
   (a) Any body which gives off light because of the energy of its own oscillatory particles is luminous; but if it merely reflects the light it receives, it is "illuminated".
   (b) Light which falls upon a body may be reflected, absorbed, or transmitted in various degrees, depending upon the nature of the object, and the wave length of the light.
3. The velocity of light is approximately 186,000 miles per second in air, but varies considerably in other media.
4. Photometry deals with the measurement of the intensity of light.
   (a) The amount of light a body receives is inversely proportional to the square of its distance from the source, and directly proportional to the intensity of the source.
      (i) The quantity of illumination is measured in foot-candles, and the quantity of light emitted is measured in lumens.

Vocabulary Expansion Required for Generalization VIII

converging pencil
corpuscular theory
diverging pencil
foot-candle
illuminate
incandescent
luminous
lumen
mean spherical candle power
opaque
optics
penumbra
photometric
photo-electric
photon
quantum theory
relativity
satellite
standard candle
translucent
transparent
umbra

Words and Terms Requiring Formal Definition

standard candle
foot-candle
lumen

Laws to be Memorized

Law of illumination.
Law of intensity.

IX. The amount of light which an object reflects depends upon the nature of the material, the polish of the surface, and the angle at which the light strikes the surface.

1. The angle of reflection is equal to the angle of incidence of light.
2. Any highly polished surface which can be used to form images by the regular reflection of light has the properties of a mirror.
   (a) All real images are inverted, but virtual images are always erect; and both types may vary in

size.

(b) The relative sizes of object and its image in a pin-hole camera are proportional to their relative distances from the opening.

(c) In all plain mirrors, the image is found to be as far behind the mirror as the object is in front of it.

(d) In convex mirrors all images are virtual, erect, smaller than the object, and located between the mirror and the principal focus.

Vocabulary Expansion Required for Generalization IX

aberration
aperture
centre of curvature
diffusion of light
focal length
opthalmoscope
parabola
principal focus
incident ray
kaleidoscope
opalescent
secondary axis
semi-gloss
vertex
virtual focus

Laws to be Memorized

Law of reflection of light.

X. Any ray of light passing obliquely from one medium into another of different optical density is refracted; but rays perpendicular to the surface are not refracted.

1. The index of refraction of any given substance is the ratio of the speed of light in air to its speed in

the given substance.

(a) The index of refraction for any two media is constant no matter what the angle of incidence of light.

(b) Total reflection always occurs when the angle of incidence exceeds the critical angle.

2. A portion of any transparent substance can be used as a lens, provided that it is bounded by two nonparallel curved surfaces, or by one plane surface and one curved surface.

   (a) Converging lenses are always thicker in the middle than at the edges, while diverging lenses are thicker at the edges than in the middle.

   (b) Lenses refract parallel incident rays so that they meet at the principal focus.

   (c) Increasing the index of refraction shortens the focal length of a lens or lens system.

3. The spherical aberration which occurs in lenses as well as in mirrors may be remedied by the use of a diaphragm or by specially ground lens surfaces.

<u>Vocabulary Expansion Required for Generalization X</u>

adulterated	range finder
angle of incidence	refractometer
atmospheric refraction	reinversion
critical angle	sine of an angle
optical density	zenith
periscope	

<u>Words and Terms Requiring Formal Definition</u>

critical angle
index of refraction

<u>Laws to be Memorized</u>

Laws of refraction

XI. Light has become extremely useful in modern civilization through the development of optical instruments which produce and control it.

1. Optical instruments depend upon a great variety of lenses and combinations of lenses in order to control light.
2. All objects seen by the eye are more distant than twice its focal length, hence the image thrown upon the retina is a real, inverted, and small image.
   (a) Only certain defects of the eye, such as far-sightedness, shortshightedness, and astigmatism may be corrected satisfactorily by means of spectacles.
   (b) One learns to judge the size of an object by the size of the visual angle if the distance is known; and conversely, if the size of the object is known one may judge the distance it is away.
   (c) Binocular vision enables us to get the perception of depth or perspective.

3. The camera is modelled after the eye and is superior to it in some respects, though inferior to it in others.
4. All microscopes form an enlarged image of the object by one set of lenses, and this image is then magnified again by another set.
5. Though telescopes may be either refracting or reflecting in character, they must first collect a large quantity of light to form a bright, real image, which is then magnified.
6. The principle of "duration of vision" makes possible the showing of moving pictures.

<u>Vocabulary Expansion Required for Generalization XI</u>

argon
astigmatism
astronomical
bifocal
camouflage
cornea
duration of vision
indirect lighting
meniscus lens
neon
"objective" of microscope
optical illusion
plano-convex
range finder

XII. All white lights including sunlight are polychromatic.

1. Light waves of different colors have different refrangibility because each color has a different wave length.
   (a) Color bears the same relation to light which pitch does to sound.
2. The color of an opaque object depends upon the color

of the light which it is capable of reflecting to the eye, and the color of light that shines upon it.

3. The color of transparent objects depends upon the color of light which they transmit.
4. Incandescent solids, liquids, and compressed gases yield continuous spectra; but luminous gases produce bright-line spectra.

Vocabulary Expansion Required for Generalization XII

absorptive spectra
achromatic light
analyser
bright-line spectra
chromosphere
complementary colors
congenital
continuous spectrum
Daltonism
dark-line spectra
dextro-rotatory
diffraction grating
discontinuous spectra
elementary colors
emulsion
fundamental colors
Fraunhofer lines
infra-red rays
Kodachrome process
levo-rotatory
manganese
mercury-vapor lamp
monochromatic
polariscope
polarized light
Polaroid
polychromatic light
primary colors
retinal fatigue
saccharimeter
solar spectrum
ultra-violet rays

Diagrams to be Learned and Activities to be Performed

The student should:

1. show that pressure in liquids is proportional to the depth and equal in all directions at the same depth.

2. demonstrate that pressure is independent of the size and shape of the container.

3. construct and use an open manometer.

4. prove that "water seeks its own level".

5. learn the diagram illustrating an artesian well.

6. construct a miniature model of a gravity water system.

7. demonstrate the operation of an hydraulic press.

8. test Archimedes' Principle by experiment.

9. show how liquids transmit pressure.

10. construct diagrams to help explain the laws of buoyancy.

11. show diagrams of apparatus used to determine the specific weights of substances.

12. use an hydrometer in various liquids.

13. use a pycnometer in determining the S.G. of liquids.

14. using an exhaust pump, prove that air expands and contracts.

15. construct a simple mercurial barometer.

16. learn to adjust and read a modern mercurial barometer; and to draw a diagram of its essential features.

17. investigate the action of an aneroid barometer.

18. demonstrate the action of barometers under increasing and decreasing pressures.

19. discover methods of collecting pure samples of gases of varying solubilities and desnities.

20. test Boyle's law.

21. operate and make a diagram of an exhaust pump.

22. construct and operate an ejector, or atomizer spray.

23. operate and make a diagram of a compression pump.

24. learn the diagram for the Westinghouse air brake.

25. demonstrate the principle of and learn the diagram for a diving bell.

26. learn a cross-sectional diagram of the caisson.

27. perform the Bacchus experiment to illustrate air pressure.

28. operate a laboratory model lift pump and learn the diagram for it.

29. operate a laboratory model force pump and learn the diagram for it.

30. learn the diagram of the chain pump.

31. construct and operate a siphon.

32. show the action of a Cartesian diver.

33. examine the construction of and watch the operation of a modern soda-acid fire extinguisher.

34. construct and use a closed manometer.

35. examine and learn the diagram of the essential parts of a gas meter.

36. construct and operate an intermittent siphon and an aspirating siphon.

37. show how an air cushion prevents the "pounding" of water pipes.

38. demonstrate the diffusion of a heavy and a light gas.

39. show the rapid diffusion of hydrogen through a porous wall.

40. demonstrate the principle of osmosis.

41. demonstrate the cohesion of water molecules.

42. show the action of surface tension.

43. show that a "free liquid" assumes the shape of a sphere.

44. show capillary action of various liquids.

45. observe the essential parts of a gas mask.

46. observe the operation of the thermostat from a hot water bottle.

47. watch the operation of a steam radiator valve.

48. heat and cool a compound bar.

49. observe the construction and operation of a metal thermometer.

50. observe the construction and operation of an electrically operated thermostat.

51. examine the construction of a compensated balance wheel.

52. examine the construction of a compensated pendulum, and test the law of the pendulum.

53. measure the coefficient of expansion for various liquids.

54. measure the coefficient of expansion for various gases.

55. prove that sound needs a material medium for its transmission.

56. learn the diagram to explain "sound ranging".

57. demonstrate transverse and longitudinal vibrations.

58. show how resonance may be produced.

59. show how interference of sound waves may produce beats, or even silence.

60. show that "singing flames" may produce beats.

61. observe various lengths of vibrating strings produce their fundamental notes.

62. demonstrate the formation of loops and nodes in a vibrating string.

63. produce nodal lines on various shapes and sizes of vibrating plates.

64. using open and closed organ pipes of various lengths, discover the relationship between the length of the pipe and the pitch of the note it produces.

65. watch the operation of and learn the diagram for the phonograph "reproducer".

66. construct and operate a simple manometric flame apparatus.

67. learn the diagrammatic explanation of the Phonodeik.

68. illustrate diagrammatically the manner in which various types of eclipses are produced.

69. learn the diagram of the apparatus used to determine the speed of light.

70. demonstrate the Law of Reflection of Light.

71. show the difference in regular and irregular reflection of light.

72. demonstrate the principle of the pin-hole camera.

73. demonstrate and construct the diagram to explain the formation of images in plain mirrors.

74. show how parallel light rays are reflected by curved mirrors.

75. show how converging rays are reflected by a curved mirror.

76. show how diverging rays are reflected by a curved mirror.

77. show how to locate the image in a concave mirror when the object is in any one of the six principal positions from the centre of curvature of the mirror.

78. show how to locate the image in a convex mirror.

79. illustrate the action of some common types of reflectors upon light.

80. show the cause of spherical aberration in mirrors.

81. show the action of parabolic mirrors as light reflectors.

82. demonstrate refraction of light by water, glass, oil, etc.

83. illustrate the cause of refraction.

84. measure the index of refraction of several substances.

85. demonstrate refraction of various kinds of light by a glass prism.

86. illustrate refraction of light by the atmosphere.

87. demonstrate total reflection and determine the critical angle of refraction.

88. illustrate the application of the principle of total reflection in a periscope.

89. operate and illustrate the action of the different kinds of converging lenses.

90. operate and illustrate the action of the different kinds of diverging lenses.

91. illustrate the cause of spherical aberration in a lens.

92. learn the diagram for a longitudinal cross-section of the human eye.

93. illustrate longsightedness, shortsightedness, as eye defects.

94. illustrate how binocular vision and the "visual angle" aid in estimating distance and the size of objects.

95. examine a lens camera and illustrate the manner in which it operates.

96. examine, operate, and then illustrate the principle of a simple magnifier and a compound microscope.

97. illustrate diagrammatically the principle of the refracting telescope and the reflecting telescope.

98. examine an optical lantern, and by a diagram show how it forms images.

99. operate and examine various types of indirect lighting fixtures; then illustrate diagrammatically the principle upon which each operates.

100. disperse compound light into its colors and then recombine these into compound light.

101. use the color disc or Von Nardoff's apparatus to produce white light by combining colored lights.

102. produce and examine bright-line and dark-line spectra.

103. illustrate diagrammatically the principle of the spectroscope.

104. illustrate the cause of the rainbow.

105. produce chromatic aberration, and show by a diagram why it occurs.

106. illustrate the principle of the polariscope.

CHAPTER VI

DATA FOR GEOLOGY I

Generalizations

I. All bodies in our solar system are controlled by the gravitational attraction of the sun about which they revolve in huge ellipses and in nearly the same plane.

1. Most modern theories regarding the origin of the planets agree that these bodies have resulted from the collection and condensation of gases and other materials about certain nuclei.

   (a) Certain of these masses of gas cooled enough to form liquid spheres, and these by further cooling developed solid crusts of rock on their surfaces.

<u>Vocabulary Expansion Required for Generalization I</u>

accretion	paleontology
centrosphere	petrology
contraction theory	planetesimal
hydrosphere	seismology
lithosphere	stellar theory
meteorology	stratigraphy
nebulae	subsidence
oceanography	tsunami

II. The crust of the earth is subject to two opposing forces: those tending to build it up; and those tending to break it down.

1. The fossil remains of marine life in rocks prove that such rocks were formed from sediment on the bottom of an ancient sea.
2. Denudation of one part of the earth's surface must be accompanied by deposition in another part.
   (a) Elevation of certain areas often results from deposition and subsidence in adjacent areas.
3. Rock strata occur in the earth's surface in the order in which they were deposited, except in the case of overthrust faults.
   (a) The succession of fossils in the rocks shows a progressive series of simple to complex life forms.

Vocabulary Expansion Required for Generalization II

anticline	mesozoic
Cenozoic	monocline
clinometer	Paleozoic
epoch	geological "period"
fault	Precambrian
fault plane	reverse fault
formation	rift valley
group	rock "series"
index fossils	rock "system"
key bed	syncline

III. The history of the earth has been divided into time intervals marked by important events such as the rise of certain kinds of animals and plants, invasions of the sea over the land, elevation of land masses, raising of mountains, and so forth.

1. The chief eras of the earth's history have been based on the kinds of life which were dominant at certain times.
2. Rock formations having the same uniform character were formed under the same conditions.
   (a) The kind of rock in a formation, together with the kind of fossils contained in it, gives an index of the conditions under which it was formed.

<u>Vocabulary Expansion Required for Generalization III</u>

Cambrian	Ordovician
Carboniferous	Permian
Cretaceous	Pleistocene
Devonian	Pliocene
Eocene	Quaternary
Jurassic	Silurian
Miocene	Tertiary
Oligocene	Triassic

IV. The atmosphere as a whole, as well as certain gases in it, has very important functions in producing and maintaining living things.

1. The atmosphere exerts pressure on all objects with

which it is in direct contact.

2. The moisture-carrying capacity of our air varies with the temperature of the air, increasing as the air becomes warmer, and decreasing as the air becomes cooler.
   (a) Air must be cooled to, or below, its dew-point before the moisture it contains will begin to precipitate.
      (i) Air which must be cooled below the freezing point of water in order to reach the dew-point will precipitate moisture in the form of snow.

3. The sun is the source of all energy in the atmosphere.
   (a) The temperature of the atmosphere decreases with the altitude.
   (b) The radiant energy of the sun is composed of many different wave lengths, each of which has certain important functions.
      (i) Certain substances will allow heat waves to pass through them while others absorb the heat waves and become warm.
      (ii) Any object which is warmer than its surroundings will radiate heat.
      (iii) Heat may be transferred by radiation, conduction or convection.
         (1) Metals are generally good conductors of heat, but many other solids, most liquids,

and gases are poor conductors.

(2) Rock and soil materials will absorb heat more rapidly than water does, but they also cool more rapidly.

(c) Convection currents result from unequal heating of a mass of liquid or gas.

(d) Air is a poor conductor of heat and, if convection currents can be prevented, air becomes a good insulator.

(i) The atmosphere of the earth tends to prevent the escape of heat from the earth's surface.

(e) Land and sea breezes, monsoons, planetary winds, and other movements of the atmosphere depend upon convection currents in the air.

(f) The more oblique the angle at which the sun's rays strike the earth's surface, the less heat per unit area is produced.

<u>Vocabulary Expansion Required for Generalization IV</u>

adiathermanous
altimeter
anemometer
barograph
conduction
convection current
diathermanous
doldrums
"exposure" of surface
horse latitudes
hydrometer
hygrometer
infra-red
isobars
isotherms
monsoon
Prevailing Westerlies
saturation point
Stevenson's Screen
thermal equator
ultra-violet

V. The original source of all water is the ocean.

1. The topography of the ocean floor as compared with land surfaces is fairly smooth.

    (a) Most deposits on the sea floor are formed from sediments which came from the continents or from the skeletons of animals and plants which lived near the ocean surface.

        (i) Ocean life is most abundant on the continental shelves.

        (ii) All marine life is dependent directly or indirectly upon the salt content of sea water.

2. Large bodies of water produce a moderating effect upon the temperature of adjacent land areas.

3. Almost all forms of tides are produced by the attraction of the sun and moon upon the earth and its hydrosphere.

    (a) The nature of a tide is dependent upon the relative positions of the sun, moon, and earth; and upon the nature of the coastline.

4. Ocean currents result from the combined effects of convection currents, prevailing winds, and the rotatory movement of the earth.

    (a) The temperature of ocean water decreases with the depth.

    (b) The principal ocean eddies have been formed under the influence of the planetary winds of the earth

and the relative position of the great land masses of the earth.

(i) Ocean currents influence the distribution of life by modifying temperature and by transporting food and oxygen.

Vocabulary Expansion Required for Generalization V

abyssal plain
atoll
barrier reef
calcareous
centrifugal force
continental shelf
continental slope
core sounding
diatomaceous ooze
dredge
fiord
fringing reef
globigerina ooze
ground swell
lagoon
neap tide
oscillatory wave
pteropod
radiolarian ooze
Sargasso
siliceous
sonic depth finder
tidal bore
tidal race
typhoon

VI. Scientific knowledge of the origin and character of the surface strata of the earth depends upon natural and artificial exposures of the rock layers.

1. Residual soils generally get coarser with depth, grading from soil at the surface to boulders and bed rock underneath.
2. Most sedimentary rocks have been laid down upon the continents or upon the continental shelves; but little is known about rocks of the ocean floor.
3. All rocks may be classified according to their origin and formation as igneous, sedimentary, or metamorphic.

(a) Both igneous and sedimentary rocks may be greatly altered in composition and structure by one or more of the agents of heat, pressure, and water.

4. Mountains are most frequently produced either by laccoliths or batholiths which form the roots of the mountain structure.

   (a) Ore deposits are often associated with batholiths.

5. Consolidation of deposits may be brought about by the great pressure of overlying beds, by the pressure resulting from earth movements, or by the chemical action of cementing materials such as silica, iron oxide, or calcium carbonate.

6. Most stratified rocks have been deposited by water, and are composed of particles fairly well assorted according to size.

   (a) Most deposits of limestone, salt, gypsum, etc., have resulted from the partial or complete evaporation of large bodies of sea water or lakes.

7. Coal is formed from the remains of plant bodies which have accumulated in lakes, swamps, deltas, etc., and which under the influence of water, chemical action, and pressure have been converted into coal.

8. Alternating beds of sandstone and shale, or of shale and limestone indicate that the area was once the fluctuating shore-line of an ancient lake or sea.

9. As the depth of the earth's crust increases, the temperature increases.

<u>Vocabulary Expansion Required for Generalization VI</u>

anthracite coal	irrupted
artesian well	laccolith
attitude of rocks	lignite
basalt	metamorphic rock
batholiths	peat
bituminous	quartzite
boss	residual soil
conglomerate	schist
denudation	sedimentary
diabase	shale
dike	sheet
erosion	silicate
erupted rock	soil creep
exfoliation	stalactite
feldspar	stalagmite
gneiss	stratum
graphite	talus
hogback	tillite
igneous	topography

VII. Weathering agents continually change the surface of the earth's crust by causing rock to disintegrate to produce soil, and by aiding in the production of new sedimentary deposits.

1. Since the earth's crust is subject to slow rising and sinking movements, all rocks will ultimately be subjected to weathering and erosion.
2. Weathering is due to the action of water, air, and temperature changes.
   (a) The rate at which rock weathers depends upon such factors as the kind of rock, the climate,

the exposure, the slope, and the amount of vegetation present.

3. Denudation, which includes weathering and erosion, tends to reduce the land surface to sea level.
4. The water in all lakes and rivers came from precipitation from the atmosphere.
   (a) Much of the rain which falls to the ground becomes either "immediate runoff" or "delayed runoff", depending upon the character and conditions of the soil mantle.
   (b) A water table is everywhere present, but at varying depths depending on the depth of the first impervious stratum and upon the amount of precipitation.
      (i) Underground water is an important source of water for wells and streams and is also an agent in the formation of ore deposits.
   (c) The presence of lakes, swamps, and vegetation decreases erosion.
   (d) Rivers give important aid to the weathering processes.
      (i) The erosive power of a river varies as the square of its velocity.
      (ii) The velocity of a river is determined by the slope, capacity and nature of the channel, and by the volume of water moving.

(iii) Erosion by a river is generally most rapid at its mouth, decreasing with decrease in the gradient of the stream.

(iv) Rivers fed by lakes or swamps carry very little sediment and erode their channels slowly.

(v) As the gradient of a river becomes less, the tendency for the river to meander becomes greater.

(vi) Rivers become mature at their mouths first.

(vii) As a river valley approaches old age, the surrounding country is gradually reduced to a peneplain by the meandering stream.

(e) Lakes are formed by some interference with the normal drainage system of an area.

(i) Any area of internal drainage where evaporation is rapid will develop salt lakes.

(ii) Lakes are only temporary geological features since they tend to become filled in, drained, or evaporated.

(iii) Areas of incomplete drainage form swamps.

5. Most coastal plains have been formed from uplifted marine plains.

Vocabulary Expansion for Generalization VII

abrasion
afforestation
aggrading
alluvial cone
alluvial fan
alluvial plain
base level
bottomset layer
butte
caldera
cone delta
corrosion
deflation
deforestation
degrading
"divide" area
delayed runoff
delta
earth column
epicontinental sea
estuary
fall-line
fault plane falls
flood plain
foreset layer
geysers
hoodoos
intermittent stream
intrenched meander
joint-plain falls
kettle lake
loess
marine plain
meander
mesa
natural levee
ox-bow lake
peneplain
playas
porosity
quarrying
rain sculpturing
rejuvenation
remnants of erosion
river terrace
saline
slip-off slope
steppe
tarn
topset
watershed
water table

VIII. The Great Plains of North America have been in earlier times part of an old sea bottom now elevated above sea level.

1. Plains may or may not be forested.

   (a) Plateaus have probably been plains which were elevated along with the mountains by crustal movements of the earth.

   (b) Erosion of plateaus proceeds like the erosion of plains, except that, since the rocks of plateaus are usually harder and the climate

much drier, the rate of erosion is slowed down.

2. Deserts are characterized by the fact that they support few forms of life.

   (a) Erosion in deserts is accomplished chiefly by changes in temperature, and by the scouring action of the wind and sand.

IX. Volcanoes do not involve strata dislocation, as mountain building movements always do.

1. Most of the volcanoes of the earth's surface lie in two zones which almost coincide with the mountain ranges and earthquake zones of the earth.

   (a) Mountain building movements are probably the real origin of volcanic activity.

      (i) Lava erupted from volcanoes is of the same general composition as the surface rocks, and probably does not come from great depths.

      (ii) Lava flows may well up from a fissure in the earth's crust and spread out over great areas of the earth's surface, forming deep lava fields of resistant rock.

      (iii) Fumaroles, hot springs, geysers, and crater lakes are found in areas in which volcanic action is in the last stages of decline before complete extinction.

      (iv) The heat which produces hot springs may

originate from a rising batholith, friction of moving rock masses, chemical action in the rock, or from the earth's hot interior.

2. Soils formed from decomposed lava are very fertile.
3. Though earthquakes may be associated with volcanoes, they are usually caused by faulting movements of the earth's crust.

Vocabulary Expansion Required for Generalization IX

agglomerate
epicentrum
fault scarp
fissure
fumaroles
geyserite
lapilli
pumice
seismograph
siliceous matter
tectonic earthquake
tufa
volcanic bomb
volcanic tuff
volcanic plug

X. The strata of mountains are rarely horizontal, but are characterized by folds and faults which may be very complicated in structure.

1. As a mountain range is denuded it tends to separate into individual units which often have high peaks or long ridges.
   (a) Mountain passes are often formed where streams head together or where glaciers have been active.
2. Mountains in the path of prevailing winds cause precipitation to be heaviest on the windward side; but give rise to deserts or semi-desert conditions on

the leeward side.

(a) In all mountain regions temperature decreases with increased elevation.

3. When uplift proceeds more rapidly than denudation, mountains remain young; but once uplift ceases, denudation gradually produces low rounded mountains with broad forested valleys as the mountain ranges are reduced in old age to a peneplain.

4. To produce glaciers in their valleys mountains must be high, cold, and so situated that they receive much precipitation.

   (a) Glaciers move at different rates depending on the size and thickness of the glacier and the slope and nature of the valley down which it moves.

      (i) The flow of ice in a glacier is faster in the middle and at the top surface since friction is greatest on the sides and the bottom.

      (ii) Glacial erosion grinds off the sharp features of the land and fills depressions with the debris.

         (1) The most characteristic effect of glaciation on a mountain region is the production of broad, smooth V-shaped valleys, truncated spurs, and hanging valleys.

   (b) The present epoch is believed to be one of many interglacial periods of warm climate characterized

by retreating continental ice sheets.

(i) Drainage was greatly affected by the continental ice sheets which blocked normal outlets, carved new river valleys, and produced vast new lakes.

(ii) Though many theories have been formulated to explain the cause of glacial epochs, the most acceptable explanation is based on the fact that temperatures decrease when the carbon dioxide content of the atmosphere decreases.

5. Mountain regions are of great economic importance to man.

<u>Vocabulary Expansion Required for Generalization X</u>

cirque
cordillera
drumlin
esker
fan glacier
fluted hill
frontal apron
geosyncline
giant kettle
glacial drift
glacial erratic
glacial milk
glacial tables
hanging valley
kame
lateral moraine
medial moraine
monadnocks
névé
nunataks
piedmont glacier
relic mountains
river piracy
roches moutonées
rock flour
seracs
snow line
striae
terminal moraine
tidal glacier
"till"
timber line
truncated spur
valley train
water gap
wind gap

XI. Climate refers to the average weather conditions of a region as observed over a long period of years.

1. Weather is the condition of the atmosphere with respect to temperature, barometric pressure, direction and velocity of the wind, humidity, and the state of the sky at any given time.
2. Latitude is the chief factor which determines climate, but it is modified in its effects by a number of other factors such as altitude, prevailing winds, ocean currents, mountain ranges, and location on a continent.
3. The winds of the earth tend to occur in belts because of the unequal heating of the earth's surface.
   (a) Areas of low pressure are generally characterized by relatively high temperatures and precipitation, while areas of high pressure tend toward lower temperatures, less precipitation, and clear skies.
4. The principal factors governing the climate of Canada are latitude and prevailing winds.
5. Rock and fossil evidence indicates that all regions of the earth have passed through cyclic climatic changes from frigid to torrid.

<u>Vocabulary Expansion Required for Generalization XI</u>

doldrums
monsoon
tornado

XII. Most of Alberta's present mineral wealth comes from oil, coal, and natural gas.

1. Coal has been formed from vegetation which accumulated in certain places and which was subsequently covered by water or sedimentary deposits, thus providing the necessary conditions for bacterial action, chemical change, and pressure.

   (a) The longer that microbian action is allowed to continue and the higher the pressure exerted upon the deposit, the higher the quality of coal produced.

      (i) The higher the percentage of fixed carbon and the lower the percentage of volatile matter the higher the heat value of coal and hence the better the grade.

      (ii) Most deposits of coal found in the plains improve in quality the deeper they are found.

2. Petroleum contains more than 1000 different chemical compounds which are of use to man.

   (a) Petroleum oil and natural gas have probably been formed from the remains of plants and animals which were buried in the clays and sands of sea coasts, bays, swamps, and lakes.

   (b) A number of structures such as anticlines, domes or other porous rock formations may serve as reservoirs for the oil and gas produced by

natural distillation.

(c) The amount of oil recoverable from an oil well depends upon the amount of gas which is dissolved, the oil, and the manner in which the gas pressure is preserved after drilling.

(d) The higher the gravity of the crude oil, the more valuable the oil.

3. Oil deposits are generally associated with gas, but gas is not always associated with oil.

4. Since Alberta has large deposits of coal and limestone, extensive iron-producing industries could be developed there if iron ore of good quality and in sufficient quantity could be found near.

5. Alberta has deposits of a large number of non-metallic ores which are present in commercial quantity.

<u>Vocabulary Expansion Required for Generalization XII</u>

alabaster	Glauber's salt
anhydrite	halite
asphalt	high gravity
Bentonite	iron stone nodules
British Thermal Unit	lode
cable tool rig	magnetite
cephalopods	placer mining
dolomite	Plaster of Paris
dome	rotary drill
drag folded	selenite
driller's bit	soap stone
edge water	sphalerite
gastropods	strip mining

Diagrams to be Learned

The student should learn to make reasonably accurate diagrams to illustrate the following:

1. a fault in stratified rock.
2. anticlines, synclines, and monoclines.
3. a mercurial barometer.
4. a rain gauge.
5. a Campbell-Stokes Sunshine Recorder.
6. an anemometer.
7. a hygrometer.
8. a maximum and a minimum thermometer.
9. the production of convection currents in air.
10. the planetary wind belts of the earth.
11. the cause of the earth's seasons.
12. a cross-section of the ocean and its floor.
13. a cross-section of the continent of North America.
14. the cause of monsoon winds.
15. the arrangement of deposits on a sinking shore.
16. the arrangement of deposits on a rising shore.
17. the arrangement of deposits on a fluctuating shore.
18. the production of various kinds of ocean tides.
19. the cause of breakers and surfs.
20. the location and direction of the chief ocean currents of the world.
21. the formation of an atoll.

22. a cross-section of a laccolith.

23. a cross-section of a boss and batholith.

24. the filling-in of lakes by vegetation.

25. the formation of stalagmites and stalactites.

26. a cross-section of the earth showing its composition.

27. cross-section of an artesian well area.

28. the production of limestone caves.

29. a cross-section of a typical falls (Niagara falls).

30. a block section of an old valley with river, levees, ox-bow lakes, and meanders.

31. the development of meanders in a river.

32. the formation of a delta.

33. cross-section of an alluvial cone.

34. cross-section of a rift valley.

35. the formation of a marine plain.

36. a cross-section of a volcanic cone.

37. a map of the volcanic zones of the earth.

38. a simplified vertical-component seismograph.

39. the formation of water gaps and wind gaps.

40. the structure of block mountains.

41. the stages in the complete erosion of mountains.

42. the formation of medial and lateral moraines.

43. a map of the continental glaciers of North America during the Pleistocene epoch.

44. the stages in the production of a mature river-valley.

45. the chief features of a weather map.

46. a map of Alberta showing the chief areas of coal, gas, oil, and mineral deposits.

47. a cross-section of an anticline containing oil-bearing sands.

48. a cross-section of a joint-plane falls.

49. a cross-section of a glacier.

50. a cross-section of a geyser.

51. the cause of a "fall-line".

Experiments and Activities to be Performed

The student should:

1. evaporate soil water showing amount of dissolved substances in it.

2. measure the angle of dip, and of strike in rock strata.

3. construct a simple mercurial barometer.

4. demonstrate the effect of increased or decreased air pressure on a barometer.

5. construct and use a wet- and dry-bulb hygrometer.

6. demonstrate convection currents in air and in water.

7. show that dry soil, wet soil, water, rock become warm at different rates in sunlight.

8. prove that the exposure of a surface modifies the heating effect of sunlight.

9. determine the dew-point under various atmospheric conditions.

10. produce spectra from sunlight and various other kinds of light.

11. demonstrate the assorting action of water in alluvial deposits.

12. determine the relative effects of salt water and fresh water in settling suspended sediment.

13. demonstrate the action of flowing water in transporting and depositing loose soil.

14. show that cold, hot, fresh, and salt waters have different densities.

15. show that convection currents are produced when warm water and ice come into contact.

16. collect and classify rocks into the three fundamental types.

17. test various rocks for the presence of limestone.

18. show that carbonated water will dissolve limestone.

19. prove that rock absorbs moisture.

20. compare the appearance of sand grains from sand dunes with grains from rivers.

21. demonstrate the principle of the seismograph.

22. compare the size of sand particles carried by slow and fast streams.

23. illustrate the process of mountain erosion.

24. show the plasticity of ice under pressure.

25. determine the proportion of an iceberg submerged in salt water and in fresh water.

26. keep a daily weather record.

27. determine the relative amounts of water in various kinds of coal.

28. determine the porosity of a piece of sandstone rock.

29. demonstrate the natural differentiation of a mixture of sand, water, oil, and air into layers.

30. pan a sample of river sand for gold.

31. examine the sand grains from tar sand after treatment with gasoline.

32. produce a sample of Plaster of Paris from a piece of gyp-

sum; reverse the process.

33. produce lime from a piece of marble.

CHAPTER VII

SUMMARY AND CONCLUSIONS

TABLE I

Summary of Data

Types of material composing the text book	Number of items of each type of material				
			Physics		
	Biology	Chemistry	Dull	M.&C.+	Geology
Generalizations	118	130	148	112	126
Words and terms of voc. expansion	385	132	294	137	270
Formal definitions		44	22	16	
Laws memorized		10	22	13	
Diagrams and activities	117	58	106	93	84
Equations		92			
Questions and exercises++	141	753	545	403	157
Words of text book instructional matter*	84075	65772	109701	74909	51324
Pages of text book material	295	261	239	287	84**

+ Merchant and Chant, Revised by Lewis Ainslie and Lang: "Elements of Physics for Canadian Schools" was the authorized text book in Physics I for some years prior to the school year ending July, 1945.

++ The total number of questions and exercises for each authorized section of the text were counted.

* Ten pages of instructional material typical for the text were selected, the number of words on each counted, and the average number per page was then multiplied by the actual number of pages of instructional material in each text.

** The geology text is printed as a manual, the pages being approximately twice the size of an average text book page.

Conclusions Regarding the Biology I Course

Generalizations

The generalizations of this course have been presented in the text by means of a series of problems, each involving certain learning activities, explanatory reading material, and exercises. Each unit problem, together with the sub-problems, leads the pupil inductively to a fuller comprehension of one or more important biological generalizations. The fact that a generalization should be "both a process and a result of that process" has been consistently kept in mind by the authors in presenting the textual material for this course. Though the Biology I course appears to provide a rather light year's work for the average student, the scope is great enough to furnish the necessary foundational concepts to enable the student to appreciate and understand better the structure of living things, the physiology of animate things, and their relationships and classifications. The main branches of Biology, such as taxonomy, ecology, genetics, morphology, physiology, adaptation, and behavior have been adequately introduced to give the pupil a well unified view of the whole field through concepts which pupils at the Grade X level can comprehend. This has been accomplished by building the instructional material around a core of approximately

117 generalizations.

Learning Load

Since Biology I is a standard three-credit course, it must be given at least three standard-length periods[1] of instruction time per week; and since a period of four weeks is recommended for review at the end of the school year, which has a total of thirty-six weeks, there remains a total of thirty-two weeks of instruction time. The maximum number of periods available to the student for instruction is therefore 96, exclusive of review. The average amount of time which the student and teacher may utilize to develop and learn one generalization would accordingly be twenty-seven minutes.

Using the data from Table I, the learning load for Biology I may be expressed as follows:

During a period of 27 minutes a student, on an average, must develop and learn one generalization. In the course of doing this he must:

1. learn at least one diagram or do one "activity" related to the generalization.
2. learn from three to four new words.
3. answer from one to two questions or exercises based on the generalization.
4. read approximately 712 words (about 2 pages of the text book).

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[1] Programme of Studies for High School. Regulations, 1943, Page 7, defines a standard-length period to be 35 minutes.

To indicate further that the learning load for Biology I is light, let us select at random one of the main generalizations and then examine the text book material used to develop it. Suppose that Generalization III (p.14 of this thesis) has been selected. This main principle, together with all its sub-generalizations, is found in Unit IV of the text book.

To develop this main generalization that "life must come from life", it may be shown that the authors use 40 pages of textual material and employ 17 sub-generalizations. In addition, they use 23 questions and 7 suggested activities as supplementary material designed to emphasize further and clarify the main concept.

Now the amount of time required for a Grade X student to read Unit IV once is approximately 80 minutes[1]; but for the purpose of thorough study most students should read the entire unit at least three times. This would require a total of approximately 240 minutes. From calculations made at the beginning of this chapter, it has been shown that there are 27 minutes of class time available for each of the 117 generalizations of the Biology I course. To learn the 18 generalizations of Unit IV there is, therefore, a total of 486 minutes; but of this about 240 minutes would be spent in

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1 Based on a number of reading-rate tests given to a Grade X Geology class over the period September to December, 1940, and believed by the author to represent the usual reading rate of an average Grade X class.

learning the textual material that contains and develops the generalizations.

Once the reading has been thoroughly done, the 23 questions listed should be answered. These are mainly short-answer questions and the average student would be able to answer them within 45 minutes. There would remain then approximately 200 minutes of regular school time for the student to do the 7 suggested experiments and activities. The student would be required to:

1. prepare a culture of bread mold, and to examine a sample of bread mold, using a microscope.

2. show how roots may develop from stems and leaves; and how stems and leaves may develop from roots (owing to the ability of plants to regenerate missing parts).

3. visit a greenhouse and find out how different plants propagate.

4. examine the parts of a complete flower by dissecting it; make cross-sections of the ovary, the anther, and the stigma; and observe prepared slides of these with a microscope.

5. obtain some eggs of a turtle, frog, or toad, and observe them as they hatch.

6. collect abandoned bird's nests and observe the materials of which they are made.

7. observe a robin or other wild bird selecting its nesting place.

Of these experiments and activities the only ones which could be done by the whole class and in regular class periods would be No.'s 1, 2, 3, and 4. The other activities are of such a nature that they would have to be done in out-of-school hours. The available class time for activities 1, 2, 3, and 4 would therefore be 200 minutes, or approximately $3\frac{1}{2}$ hours. This appears to be ample time in which to complete these four activities.

In general, then, the Biology I course appears to provide the desirable scope of an introductory course and, at the same time, to furnish the student with an adequate number of generalizations, the development of which does not demand a heavy learning load.

Conclusions Regarding the Chemistry I Course

Generalizations

This course contains 130 generalizations. In scope these embrace a very wide variety of topics and constitute an excellent introductory course. They do two chief things: (a) they furnish abundant opportunities for the student to learn the scientific method and to apply it in a variety of different situations; and (b) they give the student a considerable body of practical information about the preparation,

properties, and uses of many of the most commonly used chemicals which make modern civilization possible. The interrelationship and ultimate unity of science is emphasized throughout. This course is quite adequate in respect to the number and nature of the generalizations it emphasizes.

Learning Load

Unlike Biology I, this course in Chemistry I is a five-credit course and the maximum number of instruction periods is 160. These periods are also thirty-five minutes in length. The average amount of time, therefore, which may be devoted by the student to learning one of these generalizations would be approximately forty-three minutes.

Then, from the data in Table I, it can be calculated that, during a period of 43 minutes, the average amount of work which the student would be expected to perform in the process of learning one generalization would be as follows:

1. learn one diagram or do one activity (experiment) for every two generalizations learned.
2. learn one new word for each generalization learned.
3. memorize one formal definition for every three generalizations learned.
4. memorize one law for every thirteen generalizations learned.
5. learn one equation for every two generalizations learned.
6. answer from five to six questions or exercises based on each generalization.

7. read approximately 506 words (about 2 pages of the text book).

From the above calculations it would appear that the learning load imposed upon a student in gaining a mastery of the generalizations of the present Chemistry I course is not heavy and should be within the capabilities of the average first-year science student.

Conclusions Regarding the Physics I Course

Comparison of Two Physics I Texts

Under the heading "Physics I" in Table I, data obtained from an analysis of two text books in Physics I have been recorded. Dull, "Modern Physics" is the text book authorized since September, 1944; but prior to this, Merchant and Chant, "Elements of Physics for Canadian Schools"was the authorized text book. In comparing the two texts from the recorded data, the following significant facts appear:

1. The number of generalizations has been considerably increased in the new course.

2. The vocabulary expansion in the new course is more than double that of the old course.

3. There has been a considerable increase in all the other elements of core material.

4. The instruction time remains unchanged.

Generalizations of the New Course

The generalizations of the new course are considerably wider in scope than those of the old course. This is not due to an actual increase in the number of main topics included in the course, but rather to an increase in the scope of the relationships developed. There are more generalizations developed as well as inferred in the new course than in the old one, chiefly because a much wider relationship between physics and other sciences has been made clear. Such a trend is entirely in agreement with the chief objectives of modern science education.

Learning Load

Since the number of generalizations in the new authorized course in Physics I has increased more than 30% as compared with the number of generalizations found in the old course, there has resulted a considerable increase in the learning load for the student.

Physics I is a five-credit course and, as in the case of Chemistry I, there is a maximum instruction time of 160 standard-length periods provided for it. Since there are 148 generalizations to be learned, the average amount of time which should be devoted to mastering one generalization would

be as follows:

1. learn at least two new words.
2. learn one formal definition for every seven generalizations mastered.
3. learn one law for every seven generalizations mastered.
4. learn to draw or do at least three diagrams or activities for every four generalizations learned.
5. answer approximately four questions or exercises for each generalization learned.
6. read approximately 790 words (almost 2 pages of the text book).

Such a learning load does not appear to be heavy for an average first-year high school student.

Conclusions Regarding the Geology I Course

Generalizations

The generalizations of this course are wider in scope than those of any of the other three sciences included in this investigation. They form excellent media through which the well trained and thoroughly informed teacher may create the proper unity among the high school sciences and link them into the really tangible and practical experience of the child. The text for the geology course provides an abundance of generalizations on geology, but these too often

appear as direct statements of fact. In such a condensed form instructional material cannot furnish the student with the abundant opportunity he should have in discovering and gathering the details from which he may arrive at the generalizations himself. However, this defect may be remedied by a frequent use of the two authorized reference texts in geology, each of which forms excellent collateral material.

Learning Load

Geology I, like Biology I, is a general elective carrying three credits. There is, therefore, a maximum instruction time of only 96 standard-length periods. Since there are 126 generalizations to be learned, the average amount of time which can be devoted by teacher and class to the mastery of one generalization would be 27 minutes. From the data in Table I it can then be calculated that within this period of 27 minutes the average amount of work which the student should do to master one generalization would be as follows:

1. learn approximately two new words.
2. learn one diagram or do one activity.
3. answer one question or exercise.
4. read approximately 408 words (about two-thirds of a page of the text).

The learning load for Geology I is light. This is in large measure due to the fact that too many of the generalizations of this course are presented in the form of con-

centrated factual material, leaving too little scope for the student to exercise his own initiative in finding facts and in marshalling the appropriate evidence to make the process of generalization functional for him.

General Conclusions

The data presented in this investigation are the results of an attempt to determine the generalizations which form the core material of four of the first-year science courses of Alberta High Schools, and the weight of the learning load which each of these presents to the student.

The generalizations together with the various items which constitute the main aspects of the learning processes have been selected, organized, and listed for each science course. Conclusions were then drawn from the data for each course respecting the scope and nature of the generalizations. In addition the learning load which one generalization would, on the average, impose upon a student wishing to gain a reasonably complete mastery of the course content was estimated.

The general conclusions drawn from this investigation are as follows:

1. These courses all contain sufficient generalizations of a fundamental nature wide enough in variety and scope to constitute an adequate basis for future science

courses in a more specialized field.

2. All the courses except Geology I furnish the student with plenty of opportunity to formulate generalizations from the factual material given.

3. The learning load for reasonably complete mastery of the material of each course is not unduly great, even in the case of Physics I which presents the largest number of generalizations.

Implications

From the data of this investigation certain implications appear to follow:

1. That criticisms directed against our present first-year science courses are not substantiated by the data of this thesis, since there appear to be present in the courses investigated all the material elements essential for achieving the main objectives of modern science education--the elements of wide scope, abundant generalizations, and plenty of opportunity for the student to generalize.

2. That the courses investigated here are not too detailed or too long. The data concerning the average learning load indicate that the average student should not find abnormal difficulty in performing the work required to gain reasonably complete mastery of these courses.

3. That perhaps the reason why our present achieve-

ments in science education in the high school are falling short of the standard objectives is to be found in the methods of teaching and in the conditions under which students learn rather than in the material content of the text books used. Concurrent with attempts to improve the material content of the science courses, greater efforts should be made to improve both the teaching processes and the learning processes as they affect the student. Until science teaching in the High Schools is so conducted as to challenge and hold the students' interest and is based on a full recognition of the psychology of youth as well as upon the principles of good pedagogy in which definite relationships between the real things of a child's environment are of paramount importance, no course in science, no matter how thoroughly appropriate the content may be, can possibly give its best results.

CHAPTER VIII

CRITICISMS AND SUGGESTIONS

Biology I

In the opinion of the writer, the course in Biology I, though appropriately presented, should be improved in three ways. First, since Biology I even more than Chemistry I or Physics I carries important cultural values, it should be given a more prominent place among the first-year science courses. Biology I, perhaps more than any of the other first-year science courses, aims to improve the pupil's behavior in and adjustment to his living and physical environment. It aims to help the pupil understand himself as an integral part of his surroundings. Though biology should contribute greatly toward a favorable adjustment of the individual to his environment, it should at the same time provide him with more scientific methods of thinking and more desirable attitudes toward life in its varied manifestations. But to attain these very essential outcomes, which are fully as important as the desired outcomes of any of the other courses, more time must be devoted to this subject.

Secondly, the content of the course should be expanded to include a fuller discussion of such practical sub-

jects as those in the following list:

1. Community health problems common to many rural and urban areas should be discussed from the general biological point of view. Thus, certain disease-carrying agents, common disease-producing micro-organisms, methods of prevention or control of common diseases, and the part played by research in safeguarding community health should be important aspects of this topic.

2. Field excursions should be discussed. Instructions and suggestions should be given for carrying out these field trips which are designed to aid the student in studying systematically some of the living plants and animals found in the immediate environment of his school. A considerable number of such excursions should be required as a compulsory part of the course.

3. Foods and nutrition should be further discussed. Special emphasis should be placed on balanced diets, vitamins, and common nutritional deficiencies in man. Students should be familiar with a considerable amount of factual material on this subject, as well as with the broader generalizations, and an increased effort should be made to make this knowledge functional. Heiss[1] puts it this way: "Simply to know that a balanced diet is necessary for good health may have some value, but to make this generalization effective in everyday life one

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[1] Heiss, Elwood D. "An Investigation of Content and Mastery of High School General Science Courses". Stroudsburg Teachers' College, Pennsylvania, 1932.

must also have a knowledge of the principal nutrients in common foods, and furthermore must know what proportions of the various food nutrients make a balanced diet."

Lastly, the text book for Biology I should contain a vastly increased number of illustrations, diagrams, and pictures, together with a much greater number of objective-type test questions so designed that they would aid the child to learn and to review the more important details upon which the generalizations of the course are built.

Chemistry I

The real object of this course as it has been set forth in the authorized text is "the mastery of the fundamental principles and facts of chemistry as the science of the changes in matter".[1] The authors, in pursuing this aim, have developed a first-year course in chemistry that is informative, very coherent, and for the most part very suitable for High School students who are beginning the study of this rather specialized science.

To the writer of this thesis, however, the course has two main defects. First, it is too didactic: it neglects almost completely the intriguing stories of those brilliant personalities who have made the history of chemistry such a

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[1] Black and Conant. "A New Practical Chemistry". Macmillan Company. Preface, p. 5.

fascinating study. One of the first duties of any course should be to catch the interests and awaken the enthusiasm of the student in order that the necessary desire for further study be generated. The present course in chemistry could be made much more interesting and profitable to student and teacher alike, if less stress were placed on certain difficult topics such as: determining the formula of a compound, isotopes, atomic structure, reversible reactions, etc., and more attention given to the history of chemistry and the many ways in which modern living conditions are dependent upon this science.

Secondly, the experimental aspect of the course is not sufficiently stressed. The importance of measurement and technique should be emphasized by having the students carry out a considerable number of the simpler experiments involving measurement. Unless this is done, one of the chief aims of science education--the development of the scientific attitude in the student--cannot be successfully attained, and the student will continue to feel that learning the factual material of the text is the principal objective in Chemistry I.

Physics I

More than any other science studied in High School, physics deals with the measurement of the properties of matter. Though this course should therefore offer an abundant oppor-

tunity for the student to learn the techniques of making measurements as well as the correct way of expressing the measurements made, it is common knowledge that graduates of our high schools are too often very inefficient in both these respects. Part of the reason for this can, no doubt, be traced either to inefficient instruction or to carelessness on the part of the student; but part of the trouble most certainly can be found in the nature of the text books studied.

In the present authorized text book, a space of only two pages is devoted to a formal study of the units of measurement. Nowhere throughout the text has the author considered it necessary to discuss methods of measurement nor common errors in the techniques of measurement. Though the units of measurement used in the text are carefully defined and excellent examples of their use shown both in formulae and in examples of solutions to problems, the importance of measurement is not sufficiently emphasized. In the opinion of the writer of this thesis, much more attention should be paid to learning accurate definitions of the units of measurement, the relationship of these units one to the other, and to the proper methods of expressing magnitude in terms of these units. Actual practice in the techniques of measurement should be given by experiments in which procedures should be indicated and probable errors in techniques discussed. As in the case of Chemistry I, the Physics I course should have increased emphasis placed upon experiment, if the aim of developing a

scientific attitude in the pupil is to be achieved.

Considerable space in the currently authorized text book for Physics I has been devoted to the study of lenses and the formation of images; to the study of musical notes and the mathematical relationships existing between these; and to the construction and operation of certain rather complex optical instruments. Yet, the fundamental principles of magnetism, electricity, and the simpler machines have been omitted from this course entirely. Since, for a considerable number of students, Physics I is the only course in physics which they get in our High School, it would seem that an understanding of such things as the electro-magnet, the electric bell, the electric motor, batteries, internal combustion engines, etc. would be of far greater practical value to them than a knowledge of the construction of the microscope, the operation of the spectroscope, or an understanding of the tempered scale.

Geology I

There are four text books authorized as source material for the course in Geology I. The data given in this thesis were taken from the text which the author believes is being used most widely by the teachers of the province. Since, however, the choice of both the type and quantity of

material for this course has been left so largely to the individual teacher, there is little value in attempting to make definite criticisms of the course. There are, however, a few suggestions which the writer would like to make regarding the teaching of High School Geology. First, it should be remembered that all the out-of-doors activities of one's life time, no matter where spent, involve a continuous contact with the earth--the matrix of life and of natural law. Geology, being the study of the earth, is thus admirably suited for showing the unity of the sciences. Many of the principles and generalizations already learned by the student in physics, chemistry, and biology, reappear in geology, operating together as interacting and often interdependent factors to produce the environment we know. This aspect of geology should be consistently emphasized in teaching the course. In this age more than ever before, the student has an opportunity of coming in contact with the innumerable aspects of nature. Hence, if this first course in geology can make the science knowledge of the student functional, that is if it can enable him to see, understand, and appreciate more fully the action and interaction of natural laws in the world about him, then the time spent in the study of this course can be amply justified.

The second suggestion is that greater emphasis be put on field excursions and actual observations of geological phenomena. Special instructions, directions, and suggestions should be given to every teacher of this subject to aid him

to carry out this practical and highly motivating part of the course.

General Comment

The writer believes that the present trend of stressing the generalizations of the High School courses is one of the most progressive features of modern educational methods, but he would like to point out that this practice carries with it certain inherent dangers. Since the term generalization is so often incompletely understood, there is a likelihood that only one phase of the educative process implied by it will be emphasized. To avoid this, teachers must realize that learning the generalizations of a course involves on the part of the student not only an understanding of the broad principles of the course but the development and practice of the art of arriving at this understanding through a process of precise and cautious reasoning.

Reasoning, in turn, requires that the child have a mastery of a wide variety and a considerable number of the right kind of details, since these form the units out of which generalizations must grow.

The first danger, then, is that teachers, while stressing the generalizations of a course in high school, may not put sufficient emphasis upon the mastery of detail. This is particularly true in the case of the science courses.

Failure on the part of the teacher to emphasize the development of this aspect of the process of generalization has serious consequences, since it leaves the student bewildered by an imposing array of shallow generalities acquired chiefly by rote memory, but over which he has attained little real mastery.

It is true that a comprehension of the generalizations of our school courses is one of the primary needs of the child for self-direction in a changing society, but it is too much to expect that the student can fully realize the aims of education by learning generalizations alone.

The second danger is to be found in the tendency among teachers to take it too much for granted that the proper mental attitudes and habits required in the process of generalization will develop automatically in High School students; and that, once the details of a course have been mastered, generalization will inevitably occur. This is not only a common, but also a most insidious misconception; and it has done much to hinder really effective instruction in our schools. If the student is to learn how to generalize efficiently he must get instruction and encouragement as well as abundant practice in doing so.

Every teacher should recognize this, and he should be willing and able to help his students to develop to the fullest possible extent their capacities to reason and to generalize.

The need for teachers to be warned against the dangers above described, and the belief that care must be taken to get the proper perspective toward the teaching of generalizations is clearly shown in the following quotation[1]:

> "Education of the intellect is not storing the mind with inert forms of knowledge, but providing the child with tools of thought, and training him to use them. Education must furnish the pupil with a well-selected equipment of precise and manageable ideas and meanings mainly in the form of generalizations applicable to a wide range of situations. Some definite information thoroughly mastered is indispensable as a basis for thought and intelligent action. The selection and orderly presentation of this material is vital. An excessive number of facts taught as unrelated items impede the grasp of principles. There must be a natural growth from knowledge that is fragmentary and casual to that which is unified, meaningful, and complete.
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> "Skill in thinking comes from the use of one's equipment of ideas in solving real problems. Thinking calls for deliberation and reflection. Pupils should be given systematic practice in thinking through significant problems not only in the secondary, but in all grades of the elementary school".

Though the purpose of this thesis is primarily to discover and present in objective form the various generalizations of certain science courses of Alberta High Schools, the writer feels that the above discussion pertaining to the emphasis that should be placed upon each phase of the process of generalization should add materially to a better understanding of this concept as it is used in modern educational procedures.

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[1] Programme of Studies for the Senior High Schools of British Columbia, Bulletin I, page 15. Department of Education, Victoria, B. C.

Criticism of Thesis

This thesis is composed essentially of two parts. First, there are the data of the main investigation, the purpose of which was the selection, organization, and presentation of the generalizations found in four first-year science courses. Secondly, there is a discussion of certain supplementary topics which have been included because they have a close bearing on the main topic and are of considerable importance to science teachers. These latter include an estimation of the learning load, as well as certain opinions, criticisms, and suggestions regarding the courses investigated.

The writer feels that in the first part of this dissertation he has fairly well attained the objective of his thesis; but he is keenly aware that, in the supplementary part particularly, certain defects respecting both the data and the techniques employed have become quite apparent since the thesis was completed. In the criticisms which follow, these defects will be pointed out, and some remedies suggested.

First, some criticism may be levelled against the technique employed in obtaining the generalizations. These were obtained solely by the writer of the thesis and, therefore, to some extent at least, the selection and the relative importance attached to many of these generalizations must have been considerably influenced by his personal judgment and opinions. Error due to this personal factor could have been considerably reduced had the writer sought the help of a large number of other experienced science teachers and used

their judgments as a guide in both the selection and organization of the generalizations. Such a procedure would have required a greatly increased amount of time, but it would probably have increased the reliability of the resulting data.

Secondly, there are a number of defects in the supplementary sections, and though these sections were primarily intended to express the conclusions of the author, they could have been improved in a number of ways. Thus, in determining the "learning load", many modifying factors have not been considered. For example, no account has been taken of the fact that a large amount of the real learning process may take place outside regular school hours, owing to the child's general observation, and collateral reading as well as to his association with other children studying the same course. This factor, if it could be measured, would have the effect of decreasing the learning load. Also, in estimating the learning load, no account has been taken of the degree to which the items composing the load must be comprehended before they are considered to be "learned". The degree of comprehension demanded for each item would greatly influence the weight of the learning load, but it is a most difficult thing to measure objectively. Some sort of standard for learning load should be found, and some method of testing the degree of comprehension would have to be used in determining this standard for each science course.

In respect to the number and kind of activities,

experiments, equations, laws, etc., which have been listed as part of the learning load, the writer realizes that these have been rather arbitrarily selected. No specific number of these has been set either by the authors of the text book or by the Department of Education. The selection, therefore, had to be made by the writer of the thesis on the basis of his own experience as a teacher of these science courses. This defect could have been lessened had the opinions of a large number of other science teachers been used to develop a standard. Even this standard, however, would be little better than an approximation, since the actual number of activities, experiments, etc., are in themselves not a true measure of the real learning load. The time consumed and the effort required to perform these activities depend in large measure upon the environment of the student, the equipment he has available, and the help and encouragement given him by his teacher.

Though the above mentioned defects lessen considerably the value of this dissertation, it is hoped that what has been done here will at least serve the purpose of stimulating science teachers to further investigations regarding the use of generalizations in science education.

Research Needed

To complete the discussion on this thesis the author believes some suggestions should be made regarding research

that is still needed on the main subject of this investigation, as well as on certain topics closely related to it.

In the first place the investigation into the number and nature of generalizations contained in the first-year science courses in Alberta High Schools should be continued. Each of these science courses should be dealt with separately and the work should be done by a large number of thoroughly experienced teachers well informed of the full meaning of the concept of "generalization". The selection of the generalizations from the text books should be made independently by each teacher, but once this has been accomplished all the independently prepared lists should be used to develop a master list showing those generalizations found by the majority of the investigators. In this way a more accurate list of the generalizations from each science course could be obtained.

Having obtained the master list of generalizations for each course, the relative importance of each generalization could then be found. One measure of this could be obtained by determining the amount of space devoted to each generalization by the various text books containing it. A measure might also be obtained by finding the number of words used to develop each generalization. Another index of their relative importance could be found by counting the number of practical applications or illustrations used to explain each generalization. Still another measure could be secured by simply submitting the master list to a large number of ex-

perienced teachers and having them rank the generalizations in order of importance. Research such as this should yield valuable information on the amount of emphasis which teachers believe should be placed upon each generalization in a given course.

Much research is also needed to determine the "learning load" presented by each science course. Some of the data required could be obtained in a manner similar to that mentioned above. But, in addition to this, much direct experimental evidence is needed. A great amount of valuable data could be obtained by testing a large number of science students to determine:

1. the average normal reading rate of students studying science courses, especially first-year science courses.

2. the average number of readings which students must make of the textual material, in order to gain comprehension of each generalization as it is presented by the text book.

3. the average number of new unfamiliar words which students find it necessary to learn in each course.

4. the average number of the generalizations of each course which are found to be completely new to the student.

5. the average amount of time spent by each student in doing the necessary exercises, experiments, and activities required in each course.

6. the number of activities, experiments, equations, formal definitions, memorized laws, tests, etc. which teachers on the average require of a student.

Until all this has been done and some sort of criterion for learning load established, no reliable measure can be made of the effort which each course demands of the pupil. At present, therefore, the teacher is forced to rely upon his own judgment and experience to establish a reasonable learning load for his class.

Research should also be made throughout the province to determine for each science course the degree to which students are mastering the generalizations present in the various science courses. Tests for this purpose could be adminstered at the beginning and at the end of each school year, and a record thus obtained of the students' actual mastery of the course. Data from such a record should furnish valuable information as to the nature of the generalizations mastered; the number mastered while taking instruction in the course containing them; and the number and kind mastered without the aid of formal instruction. Research of this sort would provide science teachers with a more accurate picture of their success in achieving one of the chief aims of science education.

Finally, further research is needed to determine the validity of the criticism referred to in the introductory paragraph of this thesis. It has not yet been proven that the first-year science courses of Alberta High Schools are deficient in basic generalizations, nor has it been shown that such a deficiency, if it did exist, could be remedied by teaching these first-year science courses, not as specialized subjects, but

as one course in General Science. Only after these two major issues have been resolved by accurate evidence from experimental research, may educators feel sufficiently informed to reject or accept with confidence the modern trend of placing greater emphasis on the generalizations in the first-year science courses.

ACKNOWLEDGEMENTS

The author wishes to make grateful acknowledgement to Dr. M. E. Lazerte, Dean of the Faculty of Education, for valuable suggestions concerning the topic selected and the procedure followed for this investigation, and for his liberal assistance and inspiration in the preparation of this thesis.

To the other members of the dissertation committee, Dr. E. H. Moss and Professor L. H. Nichols, the author gratefully expresses his appreciation of the valuable assistance they have given in reading and criticizing the manuscript.